e
Atmosphe
Program

-108151) HANDBOOK FOR MAP, VOLUM
T 1: MAP SUMMARY. PART 2: MAP
MINUT , READING, AUGUST 1989. MAP SUMMARIES
FROM NATIONS. PART 3: MAP DATA CATALOGU Unclas
(International Council of Scientific Unions) 63/46 00081

ICSU

International Council on Scientific Unions

SCOSTEP

Scientific Committee on Solar-Terrestrial Physics
J. G. Roederer, President
W. I. Axford, Vice President
C. H. Liu, Scientific Secretary

MAP ORGANIZATION

MIDDLE ATMOSPHERE PROGRAM STEERING COMMITTEE
S. A. Bowhill, SCOSTEP, Chairman
K. Labitzke, COSPAR, Vice Chairman
C. H. Liu, SCOSTEP, Secretary

H. S. Ahluwalia, IUPAP
R. D. Bojkov, WMO
A. D. Danilov, COSPAR
J. C. Gille, COSPAR
I. Hirota, IUGG/IAMAP
A. H. Manson, SCOSTEP
T. Nagata, SCAR
R. G. Roper, IUGG/IAMAP
P. C. Simon, IAU
J. Taubenheim, IUGG/IAGA
T. E. VanZandt, URSI
R. A. Vincent, URSI

MAP STANDING COMMITTEES

Data Management -- G. Hartmann and I. Hirota, Co-Chairmen
Publications -- Belva Edwards, Chairman

MAP STUDY GROUPS

MSG-5 Ions and Aerosols, F. Arnold and M. P. McCormick, Co-Chairmen
MSG-8 Atmospheric Chemistry, G. Witt, Chairman
MSG-9 Measurement of Middle Atmosphere Parameters by Long Duration Balloon Flights, J. E. Blamont, Chairman

MAP PROJECTS

	Coordinator		Coordinator
AMA:	T. Hirasawa	MAC-SINE:	E. V. Thrane
ATMAP:	J. M. Forbes	MAE:	R. A. Goldberg
DYNAMICS:	K. Labitzke	MASH:	A. O'Neill
GLOBMET:	R. G. Roper	NIEO:	S. Kato
GLOBUS:	J. P. Pommereau	OZMAP:	D. F. Heath
GOSSA:	M. P. McCormick	SSIM:	P. C. Simon
GRATMAP:	D. C. Fritts	SUPER CAMP:	E. Kopp
MAC-EPSILON:	E. V. Thrane	WINE	U. von Zahn

MAP REGIONAL CONSULTATIVE GROUP

Europe: M. L. Chanin, Chairman

MIDDLE

ATMOSPHERE

PROGRAM

HANDBOOK FOR MAP

Volume 32

Part 1:
MAP Summary
Part 2:
MAPSC Minutes, Reading, August 1989
MAP Summaries from Nations
Part 3:
MAP Data Catalogue

Edited by
R. A. Vincent, Part 1
B. Edwards, Part 2
I. Hirota, Part 3

January 1991

Published for the ICSU Scientific Committee on Solar-Terrestrial Physics (SCOSTEP) with financial assistance from the National Aeronautics and Space Administration under the 1988 Middle Atmosphere Program Management Contract and Unesco Subvention 1988-1989.

Copies available from SCOSTEP Secretariat, University of Illinois, 1406 W. Green Street, Urbana, Illinois 61801.

PREFACE

The Middle Atmosphere Program (MAP) had its genesis at a conference held at the University of Illinois, Urbana in June 1976. Following earlier preparatory work, the conference was called to plan the scientific scope and methodology for the program and a major product of the meeting was the MAP Planning Document. This document summarized the scientific objectives of MAP and outlined what was then known about the middle atmosphere, that region of the atmosphere lying between 10 km and about 110 km altitude. More importantly, the document emphasized what was not known about middle-atmosphere processes and aimed to stimulate research by providing a series of recommendations for each of the topics covered. This goal was achieved in that many of the recommendations were taken up and used as the basis for a number of subsequent MAP projects.

Following a lead-in period in which a number of pre-MAP projects took place, MAP ran from 1982 until 1985 and was followed by Middle Atmosphere Cooperation (MAC), (1986-1988), and by Middle Atmosphere Study (MAS) in 1989. With the conclusion of MAP and its associated programs, it was thought appropriate to update the MAP Planning Document and to summarize how our understanding of the middle atmosphere has, or has not, progressed. Like its predecessor, this MAP Summary Document outlines current knowledge of middle atmosphere processes and provides a series of recommendations for future research. It is hoped that these recommendations will in turn provide stimulus for studies of the middle atmosphere under the auspices of the Solar-Terrestrial Energy Program (STEP).

The present document is organized along similar lines to the Planning Document, although there are some differences. There is no chapter on experimental techniques, as much information provided in the earlier document can now be found in more detail in the MAP Handbooks devoted exclusively to ground-based, rocket and balloon techniques. There are, however, two new chapters devoted to middle atmosphere electrodynamics and chemistry, repectively. These are topics which have grown in importance during the past few years and reflect the special conditions which can be attained in the middle atmosphere. The chapters of the original document were the product of working groups, but, to save time in the present situation, a small number of recognized scientists were invited to contribute chapters. As editor, I would like to thank all those involved for the valuable time and effort that they put into writing their respective contributions.

At the conclusion of MAP it is opportune to look back on its contributions to middle-atmosphere research in particular and to the atmospheric sciences in general. While it is true that many investigations of this region would have taken place irrespective of whether MAP had existed or not, it is also true that it acted as great catalyst for national and international studies of this important region. The sponsorship provided through MAP of scientific projects, working groups, symposia and workshops, and the rapid dissemination of data and reports through the widely distributed Handbooks, contributed to many of the aims of the Program being achieved. On a personal level, I found participation in MAP a rewarding experience; it was international science at its best, a view that has been widely expressed. It is to be hoped that the many links established between groups and individuals in the middle-atmosphere community can endure and be enhanced as we move into STEP. Finally, while many people and organizations contributed to the success of MAP, it is fitting to recognize especially the leadership provided by Drs S. A. Bowhill, and K. Labitzke who were Chairman and Vice-Chairman respectively, of the MAP Steering Committee from the inception of MAP to its close.

R. A. Vincent

TABLE OF CONTENTS

Preface iii
Table of Contents v
Addresses of Contributors to MAP Summary vi

Part 1: MAP SUMMARY 1
Chapter 1 Structure and Composition, J. M. Russell III, and W. Swider 1
Chapter 2 Dynamics and Transport, D. C. Fritts, R. A. Plumb, and R. A. Vincent 21
Chapter 3 Radiation, J. T. Kiehl, and P. Simon 30
Chapter 4 Theory and Models, D. G. Andrews 52
Chapter 5 Recent Advances in the Chemistry of the Middle Atmosphere, G. Brasseur 57
Chapter 6 Middle Atmospheric Electrodynamics, R. A. Goldberg, and R. H. Holzworth 65
References 77
MAP History 85

Part 2: MAPSC MINUTES, READING, AUGUST 1989 89
MAP SUMMARIES FROM NATIONS 100
Australia 100
Brazil 102
Czechoslovakia 104
Denmark 106
Hungary 108
Japan 111
New Zealand 118
Norway 122
USSR 123

Part 3: MAP DATA CATALOGUE 127
Czechoslovakia 127
Finland 128
France 130
German Democratic Republic 134
Hungary 140
Japan 142
USSR 176

CONTRIBUTORS TO MAP SUMMARY

D. G. Andrews
Hooke Institute
Clarendon Laboratory
Oxford University
Parks Road
Oxford OX1 3PU
United Kingdom

G. Brasseur
NCAR
PO Box 3000
Boulder
CO 80307-3000
USA

D. C. Fritts
Geophysical Institute
University of Alaska
Fairbanks
AK 99775-0800
USA

R. A. Goldberg
Laboratory for
Extraterrestrial Physics
NASA Goddard Space Flight Center
Greenbelt
MD 20771
USA

R. H. Holzworth
Geophysics Program
Space Sciences Division
University of Washington
Seattle
WA 98195
USA

J. T. Kiehl
NCAR
PO Box 3000
Boulder
CO 80307-3000
USA

R. A. Plumb
Department of Earth, Atmospheric and
Planetary Sciences
MIT
Cambridge
MA 02139
USA

J. M. Russell III
NASA Langley Research Center
Hampton
VA 23665-5225
USA

P. C. Simon
Institut d'Aeronomie Spatiale
3 Avenue Circulaire
B-1180 Brussels
Belgium

W. Swider
Air Force Geophysics Laboratory
Hanscom AFB
MA 01731
USA

R. A. Vincent
Department of Physics and
Mathematical Physics
Adelaide University
Adelaide
Australia 5001

CHAPTER 1

STRUCTURE AND COMPOSITION

There is a very strong and complex interaction between the basic temperature structure, the neutral and ion composition, dynamics and transport, radiation, and chemistry of the middle atmosphere. In this chapter recent developments in our understanding of the structure and composition is summarized, while progress in the other topics is dealt with in the following chapters.

1.1 Basic Temperature Structure

Knowledge of the basic structure of the middle atmosphere has improved significantly in the past decade. Measurements of thermal emissions made by a series of satellite-borne sensors, such as the downward looking SCR and PMR experiments and the limb-viewing measurements of the LIMS and SAMS sensors carried on various Nimbus satellites, have provided a global coverage of temperatures up to heights near 85 km, with height resolutions of between 3 and 10 km. Since 1978 stratospheric temperatures have been monitored by the Stratospheric Sounding Unit (SSU) on the NOAA series of operational weather satellites which has three 12-15 km thick weighting functions peaking in the 20-45 km altitude region. The instrument has provided daily measurements of the three-dimensional temperature field. These have been used for many studies of phenomena such as stratospheric warmings, long-term temperature trends, wave propagation and so on. In the next decade the SSU will be replaced by channels in the Advanced Microwave Sounder (AMSU) which will have a better vertical resolution of about 10 km.

The satellite observations have continued to be complemented by rocket measurements which provide not only 'ground-truth' for the satellite measurements but, because of their excellent height resolution, enable the fine structure due to tides and gravity waves to be studied. An important recent development has been the deployment of ground-based Rayleigh-scatter lidars which enable densities and temperatures to be measured at heights above 30 km with very high time (few minutes to hours) and height (~1 km) resolution.

The measurements, especially those made by satellites, have led to the production of improved climatologies and reference models for middle atmosphere structure, not only of temperature but also other important related parameters such as pressure, density and wind (e.g. see BARNETT and CORNEY (1985) and other references in the Handbook for MAP, volume 16). The almost global coverage provided has been especially valuable in allowing the structures of the northern and southern middle atmospheres to be intercompared; it is now clear that there are significant hemispheric differences in, not only the basic temperature structure, but also the planetary wave activity. The northern hemisphere winter stratospheric temperatures at high latitudes are warmer on average by some 5-10 K than the corresponding values in the southern hemisphere, except near the stratopause. The lower and middle stratosphere in the winter polar southern hemisphere is especially cold with temperatures falling as low as 180 K on average near 25 km altitude. Such low temperatures seem to be an important factor in the generation of stratospheric clouds which in turn appear to play a crucial role in the development of the Antarctic Ozone Hole (see 2.5.2, 5.3.2). In summer, the stratopause in the southern hemisphere is 5 K warmer than in the northern hemisphere.

Departures from zonal symmetry in the monthly means give information on the temperature structure of quasi-stationary waves. Penetration of waves with zonal wavenumbers 1 and 2 occurs most readily in winter with maximum wave amplitudes being observed near the polar stratopause and decaying in the mesosphere. The peak amplitudes of wavenumber 2 (~2–3 K) are smaller than wave 1 (~8–10 K) in both hemispheres. Significant interannual variations may occur. There are also inter-hemispheric differences in wave amplitudes with the middle atmosphere in the northern hemisphere being more disturbed than the southern hemisphere, a characteristic caused by the differences in topography between hemispheres. The greater wave activity in the northern hemisphere probably accounts, at least in part, for the warmer wintertime stratospheric temperatures noted above.

The satellite measurements have also given a better picture of the day-to- day departures from the zonally-averaged structure. A number of these transient features in temperature and geopotential height have now been identified as manifestations of travelling atmospheric normal modes, which have well defined latitudinal structures and whose generation is not related to details of tropospheric forcing. Waves of various periods have been observed, amongst them a westward propagating wave of 5-day period and a 16-day oscillation which has especially large amplitudes in the northern hemisphere winter. There is some evidence that interference of this (and other travelling waves) with the quasi-stationary waves may play an important role in preconditioning the atmosphere prior to stratospheric warmings.

Rocket and recent satellite limb soundings have proved important for the study of low horizontal-wavenumber equatorial waves. Periodicities of several days have been observed with temperature variations of up to several degrees associated with vertical structures of ~5–40 km. Spectral decomposition suggests that these disturbances are caused by eastward- propagating Kelvin waves; features due to westward-propagating Rossby-gravity waves have yet to be positively identified.

The temperature fluctuations produced by gravity waves are of too small a spatial scale to be resolved by satellites and so studies of their wave activity has relied mainly on the use of rocket soundings and more recently on lidar measurements. Amplitudes vary between ~1–5 K in the stratosphere and ~10–20 K in the mesosphere. From an analysis of meteorological rocket data HIROTA (1984) produced climatologies of wave activity which show an annual variation in activity in the high-latitude stratosphere with a winter maximum and a semi-annual variation (equinoctial maxima) in the sub-tropics.

The largest interannual variability is observed in the winter stratosphere. The most disturbed winters in the northern hemisphere tend to be associated with wavenumber 1 patterns and less disturbed winters with wave 2. Maximum variability in the southern hemisphere occurs in October and November at the time of the final warming, which occurs at a later time in the seasonal cycle than in the northern hemisphere.

Large temperatures anomalies are caused by irregularly occurring wintertime stratospheric warmings which can have a major impact on the structure of the middle atmosphere. A number of studies have been made of both the large and small scale structure associated with warmings. A noteworthy international project was the Winter In Northern Europe campaign (MAP/WINE) of 1983/84 which combined observations using satellites, rockets and ground-based sensors located in a number of countries in the northern hemisphere and focussed on high-latitude regions of Europe. Preliminary results from MAP/WINE are introduced by VON ZAHN (1987) and discussed in accompanying papers. In the disturbed conditions associated with warmings, where sharp horizontal and vertical gradients in temperature are observed, the use of all available rocket, radiosondes and ground-based data proved crucial in the retrieval of temperatures from the satellite measured radiances. As far as the large scale structure was concerned, the campaign revealed in detail the longitudinal variations of up to 50 K in temperature that can occur at a given latitude and height as well as the anti-correlation in temperature variations between the stratosphere and mesosphere. The high time resolution data from lidars and rockets revealed temperature fluctuations in the upper stratosphere on time scales of ~25 days which were related to a succession of minor warmings.

Although the generation of stratospheric warmings is not well understood, recent studies suggests a remarkable tendency for the occurrence of major warmings to be associated with solar cycles and the phases of the quasi-biennial-oscillation (QBO) in the tropical stratosphere. LABITZKE and VAN LOON (1988) show that in 3 solar cycles no major warmings occurred in the west phase of the QBO during solar minima whereas in east phases of the QBO major warmings tended to take place at the minima of the cycles.

1.2 Neutral Composition of the Middle Atmosphere

A dramatic improvement in our understanding of the middle atmosphere has taken place since the last MAP planning document was written. This has occurred primarily as a result of improved observational techniques being applied from ground, balloon, rocket, and satellite-based platforms. A series of satellite experiments were launched during the MAP/MAC time period which used limb emission, occultation, and scattering methods to provide near global, collective data sets on temperature, O_3 NO_2, N_2O HNO_3 CH_4, CO and aerosols. These included flights of the SAMS, LIMS, SAM II, SAGE, SAGE II, SME, TOMS, and SBUV experiments. The major findings from these missions are summarized in World Meteorological Organization (WMO), 1982 and WMO, 1986. In addition to these measurements, two solar occultation experiments, the Grille Spectrometer and ATMOS, were launched on Spacelab 1 and 3, respectively, and have provided measurements of a host of minor gases at a few selected latitudes. An overview of these results follows with emphasis on outstanding problems and questions. The discussion is organized according to chemical family, including odd oxygen, odd nitrogen, odd chlorine, odd hydrogen and aerosols.

1.2.1 Odd Oxygen (Oy)

There are two odd oxygen gases of interest for middle atmosphere studies. The first, ozone (O_3), is of central importance for a number of reasons including its role as a shield to Earth life from the extreme ultraviolet rays of the Sun and its effect on chemistry, radiation, and dynamical processes. The second is atomic oxygen which is important in atmospheric chemistry and energetics studies. A brief summary of current knowledge of the distributions of these gases, with discussion of future research needs, is included in the following paragraphs.

1.2.1.1 Ozone (O_3)

Extensive satellite observations of the vertical ozone profile and the total ozone amount have provided a detailed picture of seasonal variation and changes with altitude, latitude, and longitude. The results confirm prior data showing that ozone is highly variable with maximum mixing ratios occurring at ≈ 30 km in the tropics. One of the key questions regarding ozone is what, if any, are the long-term changes in the ozone profile and integrated column amount? Satellite results from different experiments are not in agreement on vertical profile changes, with some showing definite decreases and others indicating little or no trend over a 7 year period. These data are the subject of a recent report by an ozone trends panel created by the NASA, NOAA, FAA, WMO, and UNEP organizations. Regarding the total ozone amount, the panel report noted, based on Dobson data, that ozone has decreased by 1.7 to 3 percent averaged over the latitude range 30°N to 64° N between the years 1969 to 1986. It further points out that these changes are "broadly consistent" with model calculations. Wintertime decreases are much larger and are not consistent with model calculations. The Dobson network shows winter decreases of 2.3 percent between 30°N - 39°N, 4.7 percent between 40°N - 52°N, and 6.2 percent between 53° - 64°N. When satellite SBUV and TOMS data are normalized to the Dobson network and used to determine changes over the wider latitude range from 53°S to 53°N, the results show an ozone decline of about 2.5 percent over the 1978 to 1985 time period. This is the net change after corrections have been applied to the data for the effects of solar activity variations and the quasi-biennial oscillation.

The question of long-term ozone change is a critical one which should continue to be addressed both at selected ground sites and from satellites. Measurements should be made over a long time period using well-calibrated schemes that allow periodic updates with high accuracy.

Long-term observations are especially important in view of the recently discovered Antarctic ozone hole phenomenon which appears to be deepening each year in September and October. It is not unusual for column abundances to decrease to less than 30 percent of the long-term climatological average. In 1987, for example, amounts as low as 100 Dobson units were recorded - the lowest anywhere on the globe. Although evidence suggests that a likely cause of the "hole" is heterogeneous catalysed chlorine chemistry associated with extensive build-up of polar stratospheric clouds in the Antarctic winter (6.3.2), the phenomenon is poorly understood and the extent of the latitude spreading of this effect due to transport or dynamics/chemical mechanisms is unknown. It is a concern which needs to be addressed by well-understood observational techniques that provide sufficient sampling so that trends, or lack thereof, can be determined with confidence.

Another feature of the ozone distribution which is not understood at present is the lack of agreement between observed and calculated values in the upper stratosphere. Observations are 30-50 percent higher than model results above 35 km where the atmosphere is predominantly under photochemical control. Such large differences are surprising, and since independent measurements agree with one another to within 10 percent, it appears that there are fundamental problems with theory.

1.2.1.2 Atomic Oxygen

Atomic oxygen is a critical gas in the odd oxygen photochemistry and is important in controlling ozone destruction. Its high reactivity and low concentration in the stratosphere makes it a challenging gas to observe by either in situ or remote-sensing methods. As a result, global observations have not been made, and only a small number of local stratospheric measurements has been made using balloon-borne sensing. Consequently, our state of knowledge of this constituent below about 65 km has not significantly advanced in recent years. A number of mesospheric and thermospheric measurements have been made from ground-based, rocket, and space platforms by a variety of techniques, including in situ resonance fluorescence, airglow emission using the 558 nm green line due to $O(^1D)$, the atmospheric O_2 band (caused by recombination of O), mass spectrometry, resonance scattering methods, and remote sensing based on $O(^3P)$ limb emission observations in the far infrared at 63 μm. As a result, the vertical distribution is better known now than before. There appears to be improved consistency among measurements which give a value of 10^{11} to 10^{12} cm^{-3} concentration in the 90 to 100 km range, a rapid decrease to $\approx 10^{10}$ cm^{-3} at 80 km, and a continued daytime decline to about 10^7 - 10^8 cm^{-3} near 27 km. There are no photochemical diurnal changes above 80 km altitude, but at latitude range 30°N to 64° N between the years 1969 to 1986. It further points out that these changes are "broadly consistent" with model calculations. Wintertime decreases are much larger and are not consistent with model calculations. The Dobson network shows winter decreases of 2.3 percent between 30°N - 39°N, 4.7 percent between 40°N - 52°N, and 6.2 percent between 53° - 64°N. When satellite SBUV and TOMS data are normalized to the Dobson network and used to determine changes over the wider latitude range from 53°S to 53°N, the results show an ozone decline of about 2.5 percent over the 1978 to 1985 time period. This is the net change after corrections have been applied to the data for the effects of solar activity variations and the quasi-biennial oscillation.

The question of long-term ozone change is a critical one which should continue to be addressed both at selected ground sites and from satellites. Measurements should be made over a long time period using well-calibrated schemes that allow periodic updates with high accuracy.

Long-term observations are especially important in view of the recently discovered Antarctic ozone hole phenomenon which appears to be deepening each year in September and October. It is not unusual for column abundances to decrease to less than 30 percent of the long-term climatological average. In 1987, for example, amounts as low as 100 Dobson units were recorded - the lowest anywhere on the globe. Although evidence suggests that a likely cause of the "hole" is heterogeneous catalysed chlorine chemistry associated with extensive build-up of polar stratospheric clouds in the Antarctic winter (6.3.2), the phenomenon is poorly understood and the extent of the latitude spreading of this effect due to transport or dynamics/chemical mechanisms is unknown. It is a concern which needs to be addressed by well-understood observational techniques that provide sufficient sampling so that trends, or lack thereof, can be determined with confidence.

Another feature of the ozone distribution which is not understood at present is the lack of agreement between observed and calculated values in the upper stratosphere. Observations are 30-50 percent higher than model results above 35 km where the atmosphere is predominantly under photochemical control. Such large differences are surprising, and since independent measurements agree with one another to within 10 percent, it appears that there are fundamental problems with theory.

1.2.1.2 Atomic Oxygen

Atomic oxygen is a critical gas in the odd oxygen photochemistry and is important in controlling ozone destruction. Its high reactivity and low concentration in the stratosphere makes it a challenging gas to observe by either in situ or remote-sensing methods. As a result, global observations have not been made, and only a small number of local stratospheric measurements has been made using balloon-borne sensing. Consequently, our state of knowledge of this constituent below about 65 km has not significantly advanced in recent years. A number of mesospheric and thermospheric measurements have been made from ground-based, rocket, and space platforms by a variety of techniques, including in situ resonance fluorescence, airglow emission using the 558 nm green line due to $O(^1D)$, the atmospheric O_2 band (caused by recombination of O), mass spectrometry, resonance scattering methods, and remote sensing based on $O(^3P)$ limb emission observations in the far infrared at 63 μm. As a result, the vertical distribution is better known now than before. There appears to be improved consistency among measurements which give a value of 10^{11} to 10^{12} cm^{-3} concentration in the 90 to 100 km range, a rapid decrease to $\approx 10^{10}$ cm^{-3} at 80 km, and a continued daytime decline to about 10^7 - 10^8 cm^{-3} near 27 km. There are no photochemical diurnal changes above 80 km altitude, but at lower altitudes, atomic oxygen disappears at night through recombination processes. The chemical importance of this species, coupled with the lack of global data, highlights a critical need for a systematic observational program, especially in the upper stratosphere and lower mesosphere. These data could provide an important link in attempting to understand the reasons for the lack of agreement between observed and calculated ozone. It is important to note, for purposes of data interpretation, that observational and theoretical studies have demonstrated the importance of transport processes associated with breaking gravity waves in the mesosphere and lower thermosphere.

1.2.3 Odd Nitrogen (NOy)

The principal elements of odd nitrogen in the middle atmosphere include NO, NO_2, HNO_3, N_2O_5, $ClONO_2$, HNO_4, and NO_3. Only NO_2 and HNO_3 have been observed on a global scale, in this case by the LIMS experiment. The others, however, have been observed during a shuttle mission by ATMOS, which provided the first simultaneous measurements of all the main elements of the odd nitrogen family. Even though nitrous oxide (N_2O) is not considered part of the family, it is a source molecule, and is discussed in this section.

1.2.3.1 Nitric Oxide (NO)

Data on the temporal and spatial variability of this key NO_y molecule are sparse mainly because most observations have been made at specific locations using ground-based, balloon, aircraft, or rocket platforms. Recently, a limited set of data was collected from Space Shuttle at 47°S and 30°N. A variety of measurement approaches have been used, including chemiluminescence techniques, in situ optical and ion composition methods, and remote sensing using solar occultation. There is an indication from the data that NO is highly variable in the springtime mesosphere and that there is a vertical profile minimum of <10 ppbv near 75km as suggested by theory. The NO mixing ratio increases with decreasing altitude from that point reaching a peak on the order of 13 ppbv near 45km. It then declines to less than 1 ppbv at ≈ 20km. The mixing ratio increases with altitude above 75km to a value on the order of 1 ppmv at ≈ 105km. Data in this region are very sparse. Since NO is the dominant member of the NO_y family above about 35-40km altitude, it is a critical factor in catalytic ozone destruction due to odd nitrogen and, therefore, its global distribution, temporal changes, and spatial variability need to be measured so that budget studies can be conducted.

1.2.3.2 Nitrogen Dioxide (NO_2)

The general characteristics of the global NO_2 distribution are now well known as a result of recent satellite observations. The largest NO_2 mixing ratio occurs in the tropics where, at night, it reaches a peak value of ≈ 18 ppbv at 4 mb (≈ 37km) decreasing to 1 ppbv or less at 15km and 55km. There is a large diurnal variation with the daytime peak reaching only ≈ 7 ppbv at 7 mb (≈ 32km). The diurnal change observed by LIMS in the northern terminator region in May shows very good agreement with theory, and it provides a good data base for evaluating the importance of including multiple scattering in photochemical model calculations. NO_2 varies greatly with altitude, latitude, and longitude. A sharp decline with increasing latitude is observed northward of ≈ 45°N in winter (NO_2 cliff), presumably due to conversion of NO_2 to N_2O_5. The nighttime NO_2 column sum decreases as much as a factor of 6 in 25° of latitude. Very large levels of NO_2 (≈ 175 ppbv) have been observed at about 70km in the northern polar night region, and it appears that this enhancement region in the mesosphere becomes a source for the stratosphere. Since these phenomena have been observed on a global scale in only one winter, more NO_2 data are needed, especially in the southern winter period and over a long time period so that an

NO_2 climatology can be built up for the stratosphere and mesosphere. Longer-time data sets from the SAGE, SAGE II, and SME satellites are available for sunrise, sunset, and mid-afternoon conditions, but these data have not been analyzed yet for determination of any multiyear trends that may be present.

1.2.3.3 Nitric Acid (HNO_3)

Knowledge of the global distribution and variability of HNO_3 has grown considerably since 1976 primarily as a result of satellite observations and additional balloon soundings. The data indicate that the HNO_3 mixing ratio is always low in the tropics, with the peak value reaching 4 ppbv at 20 mb (≈ 26km) but declining to very low levels (<1 ppbv) at 45 and 15km, respectively. There is a hemispheric asymmetry with the largest mixing ratio (12 ppbv) occurring at ≈ 30 mb (≈ 24km) in the winter polar night region. A secondary maximum occurs in the same region at the ≈ 5 mb (≈ 36km) level. The observed asymmetry is poorly reproduced by theory and represents a key question the data have raised which needs to be better understood. A possible explanation is that an aerosol catalyzed reaction of N_2O_5 with H_2O gives rise to the winter polar enhancement but little is known to confirm this suggestion. The temporal shift from maximum levels in the Northern Hemisphere to the Southern Hemisphere is slow and appears to be essentially in phase with the seasonal cycle. Only a limited 7½ month global data set exists on this key NO_y reservoir molecule, and it is essential that seasonal and longer-term data be collected.

1.2.3.4 Nitrogen Trioxide (NO_3)

Although it is not an important component of odd nitrogen, NO_3 is important because of the role it plays in the nighttime conversion of NO_2 to N_2O_5. Optical observations of NO_3 have been made from the ground and balloons. The measurements show maximum levels of 1-2 x 10^7 cm^{-3} near 40km, which is in general agreement with theory. Broadband total column measurements suggest the presence of a possible scavenging reaction for NO_3 in certain latitude bands and seasons, but the mechanism or the reality of the process has not been confirmed due to lack of sufficient data. The implication of this scavenging may be important in the NO_y budget.

1.2.3.5 Nitrogen Pentoxide (N_2O_5), Chlorine Nitrate ($ClONO_2$) and Peroxynitric Acid (HNO_4)

These three molecules make up the remaining important elements of the NO_y family. Nitrogen pentoxide has been measured in the atmosphere only once, in this case by ATMOS using solar occultation measurements in the 1240 cm^{-1} and 1720 cm^{-1} bands. The presence of N_2O_5 has also been inferred using balloon-based diurnal measurements taken in the same 1240 cm^{-1} band measured by ATMOS. The implied profile has a peak value of 1.6 ppbv at ≈ 5 mb (40 km). This value was obtained in the data analysis by assuming a profile shape and scaling the profile until the calculated band envelope matched the observed shape. No data exist on its spatial or temporal variability. The same is true of $ClONO_2$ and HNO_4. The vertical profiles for these molecules have implied peak mixing ratios of 1.4 ppbv and 0.2 ppbv, respectively. The pressure levels of the peak mixing ratio for $ClONO_2$ and HNO_4 are ≈ 15 mb (28 km) and 24 mb (≈ 26 km), respectively. It is important that global data be obtained on all three of these gases in order to evaluate their role in the total NO_y budget. This is especially true for N_2O_5, since it is believed to be of central importance in Antarctic O_3 depletion reactions and to be a major factor in the chemistry of NO_2 conversion and subsequent HNO_3 formation in the polar night.

1.2.3.6 Total Odd Nitrogen (NO_y)

Total odd nitrogen is of critical importance in middle atmosphere photochemistry since it tends to buffer the effect of odd chlorine (ClO_y) on ozone depletion. Using 1-D models, it has been calculated that for only a 20 percent increase above the 13 ppbv NO_y level used in the model, the predicted ozone steady-state decrease due to chlorine is reduced by a factor of two. Thus far, only one experiment, ATMOS, has provided nearly simultaneous data on all the main NO_y gases. The reported observations give peak NO_y levels of ≈ 17 ppbv at 30°N and 47°S with the peaks at each latitude occurring at 2 mb (43 km) and 5 mb (35 km), respectively. The mixing ratio decreases to ≈ 2 ppbv below ≈ 100 mb (16 km) and to ≈ 8 ppbv above 55 km. NO_y is in the form of only NO for the region above 50 km and outside of polar night regions. Data on the lower limit NO_y calculated from satellite observed sums of nighttime (NO_2 + HNO_3) show that much larger NO_y values can be observed at certain times and locations. Values ranging from 17 ppbv to 26 ppbv are seen in the data at 48°S in May. These results highlight the need to collect more observations on NO_y over a wide latitude range and in different seasons in order to gain a better understanding of its distribution and variability.

1.2.4 Nitrous Oxide (N_2O)

Nitrous oxide is the main source gas for middle atmosphere odd nitrogen. Reaction with $O(^1D)$ gives rise to nitric oxide, which is a catalyst in the odd nitrogen/ozone destruction cycle. This gas has now been measured extensively from in situ as well as satellite platforms. A mixing ratio of ≈ 300 ppbv is observed in the lower stratosphere up to 30 km, and it then drops off exponentially with altitude to less than 10 ppbv above 50 km. Zonal mean pressure versus latitude cross sections show that both single- and double-peaked distributions in latitude occur, depending on the month of the year. The latitude locations of the peaks vary considerably during the year, but they are concentrated mostly in the Tropics. This behavior is consistent with observed features in both methane and water vapor. The double peak phenomenon is seasonally dependent and does not appear in measured distributions for the last half of the year. Since N_2O has its source in the troposphere and a photochemical sink in the stratosphere, it is a good tracer molecule. Further observations are needed with higher space and time resolution to aid in dynamics studies and to better define the climatology.

1.2.5 Odd Chlorine (ClO_y)

Odd chlorine has become of central importance in the middle atmosphere because of its potential for catalytic ozone destruction. The main concern has been focused on the man-made fluorocarbons, F-11 and F-12, which carry chlorine into the middle atmosphere from below. The most important product gases after dissociation include Cl, ClO, HCl, $ClONO_2$, and HOCl. Other postdissociation by-products, HF and COF_2, are important as indicators of anthropogenic chlorine input to the middle atmosphere. The main natural source gas is methyl chloride (CH_3Cl). This chemical family has been carefully studied in Antarctic ozone hole analyses, and a leading theory postulates that the hole is caused by chlorine catalyzed ozone destruction on aerosol surfaces.

The available chlorine data set is very limited and virtually no satellite observations exist. This gap will be partially filled when the Upper Atmosphere Research Satellite (UARS) is launched early in the next decade. Chlorine related gases to be measured by UARS experiments include ClO, HCl, HF, and $ClONO_2$. A brief summary of current knowledge follows.

1.2.5.1 Atomic Chlorine (Cl) and Chlorine Monoxide (ClO)

Atomic chlorine has been measured only twice and, in each case, the in situ resonance fluorescence technique was used. The measurements are very difficult to make because of low concentrations, and the observations have large error bars. The picture is much better for ClO, but it is still lacking in important details, especially concerning the spatial distribution. Chlorine monoxide observations have been made using in situ resonance fluorescence and remote techniques applied from the ground and balloons in both the millimeter and submillimeter regions. The mixing ratio distribution in the 20° to 30°N range varies from ≈ 0.1 ppbv at 27km to about 1 ppbv at 40km. Data taken from the ground during one of the recent Antarctic campaigns indicate much larger ClO mixing ratios in the lower stratosphere than were measured in the Tropics and mid-latitudes. The results at ≈ 20km, for example, show levels which are two orders of magnitude higher than standard chemical predictions, suggesting that anomalous chemistry is taking place. The most plausible theory emerging from analyses of the body of data collected during two Antarctic campaigns is that heteorogeneous chemical processes are occurring that lead to catalyzed ozone depletion by chlorine compounds. This idea is given further credence by OClO column amount measurements made at the same time which show levels 20 to 50 times higher than would be expected based on standard homogeneous chemistry. Also, the observed diurnal variation in OClO column amount is in good agreement with theory only when enhanced levels of ClO are used in the model (see Chapter 5 for further details).

The diurnal variation in ClO has been measured both from the ground, using millimeter-wave spectroscopy, and from a balloon in the microwave region. The observed temporal changes are in fair agreement with theoretical predictions. The day/night ratio of column amount above 30km has a value of about 6 and above 40km, it is about 2. The largest discrepancy with theory, again, occurs during Antarctic spring conditions. Observations there show more rapid low altitude diurnal changes than theory predicts and low- latitude observations show. More measurements of this important molecule are needed over various seasons, times and latitudes. Hopefully, much of these data will be provided by the UARS.

1.2.5.2 Hydrogen Chloride (HCl) and Hydrogen Fluoride (HF)

Each of these gases has been measured from ground-based, balloon and aircraft platforms using in situ methods and high resolution spectroscopy conducted against the solar background. In addition, a limited set of data was obtained by the Spacelab 3 ATOMS experiment at two latitudes (30°N and 47°S) in early May. All HCl results are in reasonable agreement and give a profile which is nearly constant at a level of 2 to 3 ppbv from 43km down to 35km and then the mixing ratio decreases to 0.3 ppbv at ≈ 18km. The HCl column amount appears to be increasing at a rate of ≈ 5 percent per year presumably due to continued dissociation of chlorocarbons entering the stratosphere. Results from various methods for measurement of HF are also in reasonable agreement, and they give a vertical profile with a mixing ratio of 0.9 ppbv at 50km, 0.6 ppbv at 30km and 0.1 ppbv at 15km. The observed HF increase in column amount from ground-based and aircraft measurements is about 10 percent per year.

The ratio of HF to HCl is another parameter which should be monitored in order to evaluate the relative importance of natural and anthropogenic chlorine sources in the middle atmosphere. The value of this ratio from ground-based column amount measurements is ≈ 0.2, which is in good agreement with theory. The measured profile of the ratio from satellite data gives a value of ≈ 0.2 below 25km and 0.29 above. Extended vertical profile observations of both of these gases are needed over several years time span and for various seasons and latitudes. There are indications from limited measurements that the ratio of column HF to HCl for Antarctic springtime is much larger than what it is at other latitudes and times. This implies that either HCl is converted to some other form or else it is removed almost entirely. The prevailing theory regarding these observations is that HCl condenses and reacts with other compounds on polar stratospheric cloud surfaces. This process is believed to be a key factor in the springtime depletion of Antarctic ozone alluded to earlier. These kinds of observations, coupled with long-term data, will provide key information for study of ozone change effects. It is anticipated that these results will be forthcoming from the UARS.

1.2.6 Methyl Chloride (CH_3Cl) and Carbonyl Fluoride (COF_2)

Methyl chloride is the most important natural halocarbon because of its role as a chlorine source molecule. It has been observed both in situ using cryogenic sampling methods and remotely from shuttle in solar occultation by ATMOS. The observed mixing ratio is ≈ 0.6 ppbv at 12km, ≈ 0.3 ppbv at 17km, ≈ 0.1 ppbv at 22km and 0.02 ppbv at 30km. The measurement error bars became large above about 25-30km altitude. Observations by more sensitive methods and over longer times, seasons and latitudes are needed for chlorine budget and trend studies.

Knowledge of the carbonyl fluoride mixing ratio distribution is important because of chemical partitioning questions which arise regarding the fate of the fluorine atom after the fluorocarbons are dissociated. If the COF_2 mixing ratio is comparable to HF, for example, then measurement of HF alone in combination with HCl would not be sufficient in studying the relative importance of anthropogenic and natural chlorine sources. ATMOS measured a peak COF_2 mixing ratio of ≈ 0.1 ppbv at ≈33km which then declined to ≈0.08 ppbv at 40km and ≈ 0.03 ppbv at 20km. These results suggest that COF_2 is only a small consideration in chlorine source scenario studies, and above ≈40km it can be neglected. Confirmation of these limited observations by ATOMS is needed.

1.2.7 Hydrogen (HO_y)

Odd hydrogen gases are important in ozone destruction scenarios both directly and indirectly. The hydroxyl radical OH, for example, directly affects formation of the NO_y sink HNO_3 and the ClO_y sink HCl. Hydroperoxyl (HO_2) has an indirect affect on NO_y through reaction with NO_2 to form a reservoir gas HNO_4 which, thereby, slows down the NO_y catalytic ozone destruction cycle. A third main HO_y element, hydrogen peroxide (H_2O_2), is a major HO_y sink molecule. The primary source gases for HO_y are H_2O and CH_4.

1.2.7.1 Hydroxyl Radical (OH)

The hydroxyl radical has been observed by a variety of methods using in situ resonance fluorescence, balloon-borne laser radar sounding and balloon remote sensing using far infrared emission. The results exhibit a wide range of variability. This is due in part to the diurnal variability of OH, low signal-to-noise and probable spatial variations. Mixing ratios range from 0.3 to 0.1 ppbv at 40km, 0.03 to 0.2 ppbv at 35km and ≈ 0.01 ppbv at 25km altitude. There have been attempts to determine the global distribution of OH through calculations using LIMS NO_2 and HNO_3 distributions based on current photochemical understanding. However, no global direct measurements exist. Such data are needed over extended time periods and seasons.

1.2.7.2 Hydroperoxyl (HO_2) and Hydrogen Peroxide (H_2O_2)

The vertical hydroperoxyl profile has been observed in a series of balloon flights using in situ resonance fluorescence and cryogenic sampling coupled with the matrix isolation technique. The results show a profile that increases with altitude from 0.03 ppbv at 16km, to 0.1 ppbv at 25km and 0.2-0.3 ppbv at 35km. The HO_2 column amount above ≈ 35km has also been observed from the ground using millimeter wave emission measurements. The in situ results appear to give significantly more HO_2 than is indicated from ground-based observations. The reasons for this are not understood.

Hydrogen peroxide measurements are very scant. The only reported observations were obtained using far infrared spectroscopy from a balloon platform. The measured mixing ratio obtained was 0.4 ppbv at 38km, 0.09 ppbv at 32km and 0.06 ppbv at 28km. These mixing ratio values are much less than model predictions at these altitudes and, at the same time, the HO_2 values obtained by cryogenic sampling are much greater than predictions. Therefore, there appears to be an important flaw in theoretical understanding if the reported HO_2 and H_2O_2 concentartions are representative of the mean atmosphere. Because of the key role HO_2 plays in removal of the OH radical and the importance H_2O_2 has as an HO_y sink for the middle atmosphere, it is essential that more data be collected from ground, balloon and aircraft platforms. The goal of future observations should be to measure the global distributions of these gases from a satellite so that detailed HO_y-O_y studies can be conducted.

1.2.7.3 Water Vapor (H_2O) and Methane (CH_4)

Water vapor observations in the middle atmosphere have been made for many years. It has been only recently, however, that a general consensus has been formed about the magnitude and shape of the vertical profile in the stratosphere. This has occurred as a result of development and application of improved observational techniques from balloons, rockets and more recently, satellites. The most comprehensive data base thus far has come from the LIMS experiment launched on Nimbus 7. More data have been collected since then by SAGE II on the ERBS satellite, but the results are not yet public.

The stratospheric H_2O mixing ratio is essentially constant with altitude for mid- and high latitudes at a value of about 4.5 ppmv. In the Tropics, there is an increase as a function of altitude which is consistent with the methane oxidation theory as a water vapor source. The tropical peak mixing ratio of ≈ 6.5 ppmv occurs at or just above the stratopause. A hygropause, or region of low mixing ratio is present just above the tropopause and persists during the 7-1/2 months the LIMS data spans; but it occurs primarily in the Tropics. A daily zonal mean pressure versus latitude cross- section shows regions of low water vapor that extend in the Tropics to the mid-stratosphere. At times, there are double minima that coincide in latitude with the N_2O double maxima referred to earlier. There also appears to be a wintertime H_2O enhancement in the 18-20km range at high latitudes poleward of 50°, where the mixing ratio reaches ≈ 6.5 ppmv. Unfortunately, this rather detailed view of the H_2O distribution and its variability exists only for the 7½ months of the LIMS data, from November 1978 to May 1979. Hopefully, the SAGE II results will significantly enhance this data base; but SAGE II data will probably not extend down to hygropause levels. Global data are needed over a several year time span so that a better climatology can be constructed. Also, global mesospheric measurements are needed in order to study important HO_y-O_y processes that are unique to that atmospheric region. There is only a limited amount of mesospheric water vapor data available. Measurements have been made from the ground using microwave observations and from rockets using in situ positive ion measurements, N_2 measurements and remote infrared and far infrared observations. Also, a few measurements have been made from the space shuttle platform using solar occultation in the infrared. The data indicate that there is a variable but strong, decreasing, water vapor gradient in the 55 to 80km range. Many more observations are needed to confirm this feature and to better characterize it.

Methane measurements have been made by a variety of techniques using both in situ and remote sensing approaches. The most extensive data set is the multiyear data base provided by the Nimbus 7 SAMS experiment. These results show CH_4 variations with time which are very similar to the N_2O changes discussed earlier. The zonal mean pressure versus latitude cross-sections for various months show that in January, for example, there is a single peak in the mixing ratio contour plot tilted to the south which gradually changes to double peaked in March and then single peaked in May and tilted to the north by June. Like N_2O, the double peaks do not appear in the last half of the year. The mixing ratio varies from $\approx$ 1.2 ppmv at 22km to $\approx$ 0.7 ppmv at 40km and 0.2 ppmv at 55km.

The zonal mean pressure versus latitude cross sections for N_2O, CH_4 and H_2O in any single month have features that are well correlated. There is very good agreement, for example, in the location of the CH_4 and N_2O double maxima and the H_2O double minima. These and other correlations support the idea that CH_4 and N_2O rich air from the tropical tropospheric source region is carried upward by the net circulation along with H_2O poor air from the tropical "dry reservoir" hygropause region in the lower stratosphere. More observations for a longer time period are needed so that the implications of the data for study of the general stratospheric circulation can be evaluated.

1.2.8 Aerosols

The flights of the SAM II, SAGE and SAGE II satellite experiments are providing an evolving global aerosol climatology picture. In general, five major zones are evident in the data base. There are three regions of relative aerosol maxima in the 75°S to 40°S, 20°S to 20°N and 40°N to 75°N range and two areas of relative minima in aerosol loading in the 40°S to 20°S and 20°S to 40°N range. The observed global background aerosol load for nonvolcanic conditions appears to be $\approx 0.5 \times 10^9$ kg. The long-term trend in stratospheric aerosols is governed by volcanic perturbations with the altitude and latitude of the eruption being the important parameters that determine when and to where material is mixed after an eruption. The polar regions show a large variability in aerosol amount depending on the stratospheric polar vortex location and temperature. Aerosol tracer studies have shown that the polar vortex restricts aerosol motion and tends to entrain the aerosol preventing transport to regions outside the vortex. Polar stratospheric clouds (PSC's) have been identified and are observed to be a localized phenomenon that occurs only in the cold winter polar vortex of both hemispheres. These PSC's have become even more important recently in view of theories for Antarctic ozone hole formation which invoke hetergenous chemistry arguments. A typical value for aerosol extinction for nonvolcanic loading conditions is on the order of 10^{-4} km^{-1} in the range from the tropopause to about 25km altitude. This value can be many times larger after a volcanic eruption. It is important that monitoring of aerosol conditions of the middle atmosphere continue well into the future. Such data are needed in radiation and chemistry studies and they are required for reduction of data from other remote sensing experiments that are affected by aerosol contamination in the spectral regions being used. Unfortunately, there are no aerosol satellite experiments planned for launch after the current SAGE II experiment is terminated.

1.3 Ion Composition and Ion Chemistry

Great strides have been made in our knowledge of the ion composition and ion chemistry of the middle atmosphere since MAP's inception. In fact, there were no in-situ stratospheric data prior to MAP. This progress is briefly reviewed here. Most advances concern measurements in the stratosphere and troposphere, although there has been some progress at mesospheric altitudes. Important uncertainties remain, mainly in regard to the identities of the negative ions in the mesosphere and their chemistry.

1.3.1 Positive Ions

The positive ion composition and chemistry is fairly well understood. When air is ionized the principal ions generated are normally O_2^+ and N_2^+. Since the latter ions rapidly charge transfer with O_2, one may assume the initial ions are all O_2^+ ions. The main exception pertains to the quiet daytime mesosphere (D-region) where a window in O_2 absorption allows the 10.2 eV H Ly α line to ionize the NO in the D-region. However, the pioneering work of Narcisi and Bailey found that cluster ions of the type $H_3O^+.(H_2O)_n$ were prevalent in the D-region rather than NO^+ or O_2^+ ions, the principal ions of the E-region. At first, there was some concern that these rocket measurements may have been contaminated by water vapor, a notorious out-gassing component. However, additional measurements by Narcisi and co-workers plus similar results by scientists at NASA, Univ. of Bern and the Max-Planck Inst. at Heidelberg, left no doubt that hydronium ions or proton-hydrate ions (PH) were the dominant ions of the D-region. These cluster ions can be dissociated in the sampling process by the electric draw-in field and by their passage through the shock wave normally present during rocket flight. The latter problem is especially exacerbated in the lower D-region where the rocket's speed and the ambient gas concentration are substantial.

In general, for the quiet D-region, the transition from simple ions (O_2+ and NO^+) to hydronium ions take place near 82 km by day and 86 km by night (NARCISI, 1973). REID (1977) demonstrated the influence of high and low temperatures and/or water vapor mixing ratios upon the positive ion composition of the quiet D-region. However, detailed comparisons of models and actual measurements are rare and undoubtedly such comparisons would show the need for additional rate coefficient measurements. Many of the three-body rate coefficients in the lengthy transition scheme from NO^+ ions to $H_3O^+.(H_2O)_n$ ions have never been measured. This fact is troublesome, especially as some temperature dependences are appreciable.

A case in point is the NO-enhanced winter anomaly of the D-region where, for at least one event, NO^+ was recorded to be the dominant ion down to a rather low altitude, 71 km. Detailed comparisons of disturbed D-region measurements with a model lead to the conclusion (SWIDER and NARCISI, 1983) that NO^+ ions are depleted too rapidly if the conventional NO^+ clustering chemistry is assumed.

For the disturbed D-region, where O_2^+ is the precursor ion, the transition altitude from NO^+ and O_2^+ ions to hydronium ions is lower than for quiet conditions. This situation may be attributed to the fact that O_2^+ ions change to $H_3O^+.(H_2O)_n$ ions at a rate somewhat slower than for NO^+ ions, and because for a disturbed event (higher electron concentrations) dissociative recombination of O_2^+ and NO^+ is more probable relative to their transition chemistry.

There are few ion composition measurements in the lower D-region where sampling problems can be severe. ARNOLD and VIGGIANO (1982) have made mass spectrometric observations down to near 55 km in a weak aurora. Fortunately, the positive ion composition appears to be well-determined (SWIDER, 1984) simply from thermodynamic relationships below about 65-70 km. This is especially fortunate since there are no data whatsoever between about 55 km and 40 km, the highest altitudes attained by balloons. From about 40 km to 70 km the dominant positive ions appear to be $H_7O_3^+$ and $H_9O_4^+$. There appears to be sufficient water vapor at these altitudes so that the relative distribution of hydronium ions appears to be dependent mainly upon temperature. Lower temperatures favour heavier ions (less collisional dissociation).

No ion composition measurements of the stratosphere existed prior to MAP. Under the leadership of Arijs and his co-workers at the Belgium Institute for Spacial Aeronomy, and Arnold and his colleagues at the Max-Plank Institute for Kern-Physik in Heidelberg, enormous progress has been made.

The situation in the stratosphere is relatively simple, even though the actual chemical rate equations involve a substantial number of terms. Hydronium ions are important but the principal ions are mostly hydronium ions with one or two water molecules replaced by acetonitrile (CH_3CN) molecules. Thus, although the positive ion chemistry becomes more complex, the data can be modelled reasonably by assuming that the unmeasured reactions proceed at their kinetic rate. ARIJS and BRASSEUR (1986) calculate $H_9O_4^+$ to be the dominant ion in the upper stratosphere (40 to 50 km) with $H^+.CH_3CN.(H_2O)_3$ dominant below this region down to about 20 km followed by a mix of ions below this height. From ground level up to about 6 km (EISELE and McDANIEL, 1986; ZIEREIS and ARNOLD, 1986) $NH_4^+(H_2O)_n$ are major ions. Other ions near ground level include species whose origin is associated with the terrestrial vegetation (EISELE and McDANIEL, 1986).

1.3.2 Negative Ions

Our knowledge of negative ions and their chemistry is less satisfactory, especially in the mesosphere (D-region). First of all, Narcisi and co-workers (e,g., NARCISI et al., 1983) consistently have observed a layer of heavy negative ions centred near 85 km. These observations are supported by the data of ARNOLD et al. (1982). Gas phase chemistry cannot be the source of these ions. The latter authors suggest meteoric dust may be responsible. This layer may explain the commonly observed "ledge" of electron density in the upper D-region, i.e., a very strong positive gradient, d[e]/dz, near 85 km. Other factors which may contribute to this "ledge" include a sharp decrease in NO near this altitude and a transition from NO^+ and O_2^+ ions to hydronium ions. The latter ions recombine 3-5 times faster with electrons than do either NO^+ or O_2^+ ions. GANGULY (1984) reported large negative ion layers at 85-90 km for one-third of the evenings studied with the Arecibo backscatter radar.

Negative ions are thought to be important below about 70 km by day and 80 km by night, i.e., the altitudes where $\lambda = 1$, (λ being the ratio of electrons to negative ions). The principal negative ions of the D-region are believed to be species like HCO_3^-, CO_3^- and NO_3^- with perhaps an attached water molecule or two, although the hydrates of HCO_3^- and CO_3^- are probably less abundant than the core ions in the mesosphere (KEESEE et al., 1979). The identities of the negative ions and their abundance are very important in the daytime mesosphere where considerable detachment of electrons from negative ions takes place. Although the unhydrated eight-negative ion scheme of SWIDER et al., (1978) is undoubtedly inexact, their model reproduces well the electron distribution for an SPE-disturbed D-region. No significant difference in ion chemistry should occur in going from the quiet to the disturbed D-region (SWIDER, 1988a) just as in the more simple case of the disturbed and quiet E region. The total ion concentration is always far less that the total neutral particle population.

The identity of the ions is somewhat less important in the stratosphere where attachment completely overwhelms detachment. Negative ions appear to be most massive near 35 km where sulphuric acid leads to complex ions like $HSO_4^-.(H_2SO_4)_n$ and $HSO_4^-.(HNO_3)_n$ (Arijs et al., 1982). On one particular flight, ARNOLD and QIU (1984) observed that just two ions, $HSO_4^-.(H_2SO_4)_2$ and $HSO_4^-.(H_2SO_4)_3$, comprised more than half of the total negative ion population. Below

35 km, $NO_3^-(HNO_3)_m.(H_2O)_n$ ions are important (VIGGIANO et al., 1983), even at ground level (EISELE and McDANIEL, 1986). The major negative ion from about 33 km down to at least 15 km is $NO_3^-.(HNO_3)_2$.

The chemistry of negative ions in the middle atmosphere is rather incomplete in regards to measured rate coefficients. BRASSEUR and CHATEL (1983) listed more than 150 processes. Much more than half required an estimate value. Fortunately, most ionic rates proceed near the kinetic collision rate and hence model results are in reasonable accord with the measurements irrespective of the enormous (uncertain) algebra involved. However, derivation of minor neutral species from a comparison of a model with data must be viewed with caution.

1.3.4 Summary of Ion Composition.

Figure 1.1 depicts the principal ions and mean ion masses as derived from both models and mass spectrometric data from ground level to 70 km (from SWIDER, 1988b). Our knowlege of the positive ions appears to be more certain than for the negative ions.

At the top of the homosphere, not shown in the figure, NO^+ and $O2^+$ are the principal positive ions down to near 86 km at night and 82 km by day. Three-body processes and switching reactions convert these ions to hydronium ions, $H_3O^+.(H_2O)_n$ with decreasing height below these altitudes. In the lower D-region, the relative composition of the hydronium ions is determined well through their thermodynamic criteria (temperature and absolute water vapor concentration must be known). Near and below 40 km, acetonitrile, CH_3CN replaces one or more water molecules in the hydronium ion. In the lower troposphere, there is sufficient ammonia for NH_4^+ to be the core ion.

The chemistry of the positive ions, as implied by the above, is reasonably well understood although many ionic rate coefficients are unmeasured. One troublesome area arises in regard to the conversion of NO^+ to hydronium ions. In two instances where a model is compared in detail to disturbed D-region data (SWIDER and NARCISI, 1983), NO^+ is found to cluster less rapidly than thought. In particular, $NO^+ + CO_2 + N_2 \rightarrow NO^+.CO_2 + N_2$ appears to be more effective than $NO^+.N_2 + N_2 \rightarrow NO^+.N_2 + N_2$. This problem probably relates to an uncertainty in key processes including certain intermediate reactions which are only estimated to date.

The negative ion population and chemistry is certainly less well understood. The more serious problem would appear to be at mesospheric heights where an exact knowledge of the individual negative ions are important since detachment by photo and chemical processes has a major impact upon the electron population. (The influence of electrons and negative ions upon electromagnetic wave propagation is inversely proportional to their masses of course.)

There is some evidence that a cloud of fairly heavy negative ions persists near 85 km. Their origin may be attachment to meteoric debris since their existence is not possible through gas-phase chemistry. The prevalence of these ions is somewhat uncertain but if they are significantly abundant they may be at least partly responsible for the so-called D-region "ledge" in electron density at these altitudes.

In the stratosphere, the negative ion mean mass maximizes at 400 amu (Figure 1) near 35 km. This heavy mass is a result of the relatively high sulphur oxide concentrations in this region. Major negative ions near 35 km include $HSO_4^-.(H_2SO_4)_2$ and $HSO_4^-.(H_2SO_4)_3$ with masses of 293 and 391 amu, respectively. Nitrites become prominent with decreasing altitude and $NO_3^-.(HNO_3)_2$ at 188 amu

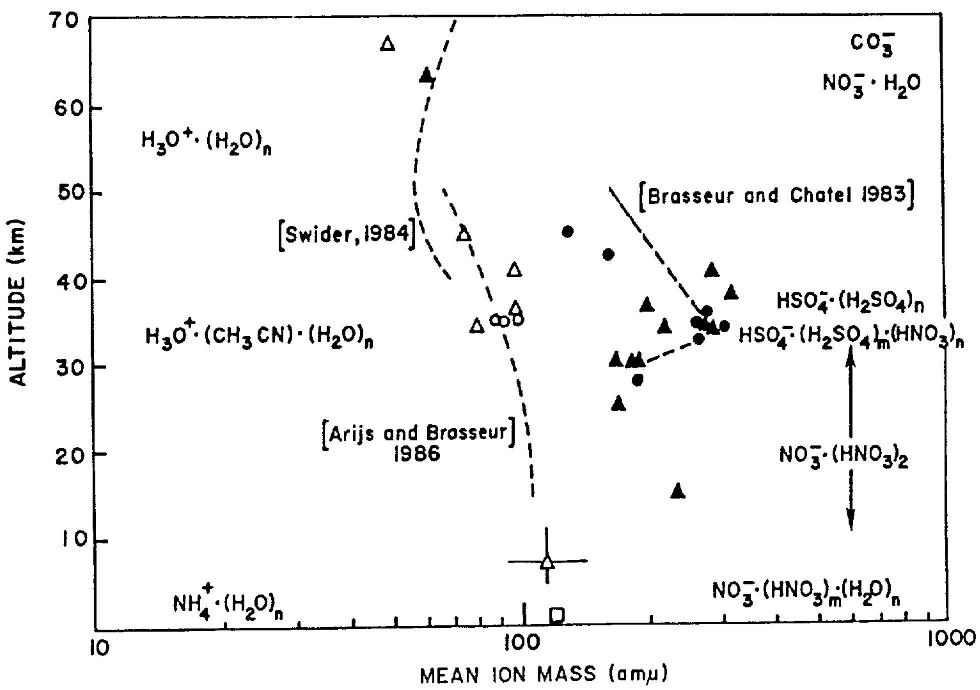

70
60
50
40
30
20
10
ALTITUDE (km)
10
100
1000
MEAN ION MASS (amμ)
CO_3^-
$NO_3^- \cdot H_2O$
$H_3O^+ \cdot (H_2O)_n$
[Brasseur and Chatel 1983]
[Swider, 1984]
$HSO_4^- \cdot (H_2SO_4)_n$
$H_3O^+ \cdot (CH_3CN) \cdot (H_2O)_n$
$HSO_4^- \cdot (H_2SO_4)_m \cdot (HNO_3)_n$
[Arijs and Brasseur] 1986
$NO_3^- \cdot (HNO_3)_2$
$NH_4^+ \cdot (H_2O)_n$
$NO_3^- \cdot (HNO_3)_m \cdot (H_2O)_n$

Figure 1.1

appears to be a major negative ion from about 35 km down to 15 km with hydrated forms of this ion becoming significant with a further decrease in altitude.

Gerdian condenser results have led to claims of both much lighter and much heavier ions. Such conclusions have been challenged by MEYEROTT et al., (1980) on the basis of experimental problems. The discussion here and more fully elsewhere (SWIDER, 1988b) basically supports their argument. Claims of very light mobilities, as associated with H_3O^+ ions are compatible with both the mass spectrometric observations and theory. Claims of very heavy ions, ~1000 amu, appear to be suspect also, although a limited number might not easily be detected by the mass spectrometers, nor play any great role either. It is significant that stratospheric aerosols have little influence over the total ion concentration (ROSEN et al., 1985). Some correlation between narrow layers of condensation nuclei and positive ion concentrations were noted. Hence, perhaps rather massive ions may exist from time-to-time over narrow height intervals.

1.4 Recommendations

1.4.1 General Recommendations

The body of data collected on the middle atmosphere thus far emphasizes the fact that it consists of a coupled system involving interactions among processes (i.e. chemistry, radiation and dynamics/transport) and atmospheric regions (i.e., thermosphere, mesosphere, stratosphere and troposphere). Consequently, simultaneous measurements of various processes in these different regions should be a goal of future observational programs. It is clear, for example, that adequate understanding of ozone changes due to chemistry requires simultaneous measurements of key elements in the main chemical families controlling ozone (i.e. NO_y, ClO_y and HO_y). Also, because ozone and other gases are further controlled by transport processes in some regions, temperature and thus derived or observed dynamical quantities (e.g. winds, potential vorticity and Eliassen-Palm flux - see Chapter 2) are required for proper data interpretation. One example of chemistry/dynamics interaction noted in Section 1.2.1.1 is the rapid decline of NO_2 column amount with latitude at high winter latitudes. This occurs presumably because of chemical conversion of NO_2 to N_2O_5 which is either slowed down or accelerated depending on the time an air parcel spends in polar night or sunlight. This is controlled by the strength and location of the circumpolar vortex. It is essential, therefore, that the capability for simultaneous observations of chemical and dynamical processes be included in future measurement system designs and observational campaigns.

Another general requirement is the need to make global long-term (multi-year) observations, especially of ozone and key parameters which influence its distribution (e.g. temperature, solar flux and selected constituents). This requirement places stringent bounds on long-term calibration system stability for absolute measurement approaches (e.g. limb emission, limb scattering, or backscattering approaches), which is difficult to achieve. The problem is greatly alleviated when the occultation method is used, but there are still challenges to be overcome.

It is recommended that the current program of ground-based, rocket, aircraft and balloon observations be continued. These programs serve valuable purposes which have already been demonstrated (e.g. discovery of the Antarctic ozone hole was made using a Dobson instrument; MST radar has provided a significant data base for study of gravity waves; ground-based microwave observations have provided the most extensive data set available on mesospheric H_2O; and virtually all chemical data in the Antarctic has been collected using ground-and aircraft-based platforms). Such systems have also been shown to yield valuable scientific data in major campaigns, with MAP/WINE being a prime example. Finally, these platforms provide the opportunity to explore new measurement methods; to pursue difficult observations such as measurement of tenuous radical species (e.g. HO_y gases); to conduct comprehensive chemistry studies, especially from balloon platforms; and to test and prove methods that can be used for validation of satellite observations.

The last general recommendation is that agencies emphasize application of small Explorer class satellites, in addition to large observatories (like the Upper Atmosphere Research Satellite). This approach will allow more rapid response to changing scientific needs and will provide a way to fill the data gaps that exist between the operational periods of larger spacecraft missions.

1.4.2 Specific Recommendations

Temperature

Despite the advances made in MAP, many of the statements made in the corresponding section in the MAP Planning Document still apply and bear repeating. For example, on the need for continuing measurements the document stated "The importance of the continuation of the current effort in temperature measurement cannot be overemphasized. The need exists to distinguish between climatic trends and cycles of temperature changes of one degree or less over several years. For these purposes it is essential that measurement standards be retained and intercomparisons made between the data from different types of sensors". The closing of meteorological rocket stations over widely different latitudes and the consequent reduction of firings is a particularly serious problem as rocket data are crucial for calibration of satellite measurements both in order to correct for drift and to facilitate retrievals during disturbed conditions. This problem may be partly alleviated by a more extensive network of Rayleigh-scatter lidars to provide "ground-truth", especially if they are operated on a more continuous basis.

The poor height resolution of the current generation of satellite borne instrumentation in the 70-120 km region means that this region is still not well understood as far as temperature structure is concerned, with most data coming from relatively infrequent rocket and lidar soundings. The expansion of lidar facilities to a wider range of locations will be an important factor in improving understanding of the mesosphere and lower thermosphere. The position regarding satellite data should improve greatly in the 1990s with the launch of UARS, currently planned for 1991. This will carry instruments to observe middle atmosphere and lower thermosphere temperature, constituents (both using limb sounders) and winds (directly by measuring Doppler shifts), as well as energy input from the magnetosphere and the sun. A coordinated ground-based and in situ campaign is being planned and should provide excellent opportunities for cross validation between various methods, and for studying any given phenomena in much greater depth.

Neutral Composition

Specific recommendations for measurements of each gas were noted in the above. The following comments are provided to amplify on these measurement needs where appropriate.

1.4.2.3 Odd Oxygen

The apparent decline in total ozone reported by the Dobson network in the Northern Hemisphere and the observed ozone year-to-year decreases in Antarctica during springtime highlight the critical need for continued and intensive observations of ozone both from the ground and from orbit. It is important to collect sufficient data over a wide geographic range, preferably globally and over a long time period (years) so that more information regarding trends can be assessed. The goal should be to develop global maps of monthly means and variances of total ozone and ozone mixing ratio on selected pressure surfaces. A critical need also exists for global measurements of atomic oxygen from the mid-stratosphere to the thermosphere because of the strong chemical role this constituent plays throughout the middle atmosphere. Measurements using both in situ and remote methods are needed.

1.4.2.4 Odd Nitrogen

While much has been learned about the odd nitrogen distribution using balloon, rocket and satellite techniques, the data only points to the need for more extensive observations. It is especially important to make simultaneous measurements of NO, NO_2, NO_3, N_2O_5, HNO_3, $ClONO_2$ and HNO_4 in polar regions during polar night and early spring to study partitioning of the NO_y family, to evaluate hetergeneous chemistry scenarios and to assess the importance of high altitude production of NO_y as a source for the stratosphere. Such observations are also needed on a global scale over a long time period to develop a climatology, to define the morphology of these constituents and to provide an appropriate data base for NO_y budget studies.

1.4.2.5 Odd Chlorine

Little is known about the global distribution of the ClO_y gases Cl, ClO, HCl, HOCl, CH_3Cl and HF. It is important, therefore, that programs be initiated to determine the global morphology and changes in the mixing ratios of these gases over a long time period so that a climatology can be developed to delineate seasonal, latitudinal and temporal variations. Measurements should be made using ground, balloon, rocket and satellite methods, where possible. The observations of enhanced chlorine in Antarctica, recent evidence of elevated chlorine levels (HOCl) in the Arctic and compelling data suggesting that the Antarctic ozone hole is caused by chlorine catalyzed chemistry emphasize the need for these observations.

1.4.2.6 Odd Hydrogen

Essentially no information is available on the latitudinal, seasonal, or temporal changes in the odd hydrogen gases OH, HO_2 and H_2O_2. Global observations are required, as well as measurements at selected latitudes by balloon techniques or other means so that the character and variability of the profiles can begin to be defined. Measurements of the source gases, H_2O and CH_4, also need to be continued in order to confirm observed features and to develop a climatology.

1.4.2.7 Aerosols

The importance of aerosol observations as a tracer of motions in the atmosphere, for use in heterogenous chemistry studies and for application in stratospheric radiation budget studies is now clearly established. There is a strong need for continued global observations of aerosols from satellites over a long time period, especially in the polar regions where heterogenous chemistry is important. Aerosol observations are also needed for use in interpretation of channel contaminant effects in remote sensing of gases.

Ion-Composition

A host of problems pertain to a rather narrow altitude regime, 85-90 km, including the D-region ledge, NLC, and a layer of rather heavy negative ions. Transport is ill-defined here, and hence the distributions of H_2O, NO, O, O_3 and O_2 (1_Δ), gases important to the D-region and prominent airglow features (OI at 557.7 nm, NaI at 589.3 nm, OH Meinel Bands). An intense co-ordinated study is needed, preferably at high latitudes for both warm (winter) and cold (summer) temperatures. Super Camp is planned for the latter case.

Very few observations of negative ions and electrons exist for the lower half of the D-Region, 50-70 km. This lack of data leads to substantial uncertainties in modelling this region where electrons, although few in number, are still significant to electromagnetic propagation at low frequencies. Precision measurements would be very welcome. (AFGL workers will attempt to measure electrons in this region by first converting them to SF_6^- ions).

CHAPTER 2

DYNAMICS AND TRANSPORT

2.1 Introduction

The current state of our knowledge of dynamics and transport in the middle atmosphere are briefly discussed. An extensive review of these processes appeared in WMO (1986). A key to improved understanding has been the satellite radiance measurements which enabled middle atmosphere winds to be determined indirectly via the thermal wind equation on a global scale since about 1973. These measurements were complemented during the MAP period by direct wind measurements from a growing network of ground-based remote-sensing radars. The radars measurements (see Handbook for MAP, volume 13 for a description of techniques) usually have good spatial and temporal resolutions and can be made on a continuous basis, extending upward from heights between 60 and 80 km to heights greater than 100 km. They have been especially important not only for studies of the prevailing motions but also for the detailed information they have provided on the smaller scale dynamics associated with tides, gravity waves and turbulence.

Studies of small-scale dynamics have also benefited greatly from the continued development of sophisticated in situ rocket and balloon techniques. The high spatial resolutions achieved are crucial for understanding of turbulence processes and their association with wave parameters. The improvements in our understanding, both theoretical and experimental, of the role of breaking or dissipating waves in determining the mean state of the middle atmosphere has been one of the important developments of the past decade. Progress has been aided by programs such as MAP/WINE, STATE and MAC/EPSILON which have brought together a number of techniques, ground based and in situ, for detailed intercomparisons of wave and turbulence processes.

A consequence of the global overview provided by satellites has been the realization that the circulation and general large scale dynamics of the northern and southern hemispheres can have marked differences, especially in winter, and that they constitute in effect, two different atmospheres. A realization that led to the formulation of the Middle Atmosphere Southern Hemisphere (MASH) project in MAP. The dynamical differences arise through the very different topographic and continent/ocean distributions between hemispheres which lead in turn to differences in the forcing of large-scale waves and probably smaller-scale gravity waves. The crucial role that transport by the general circulation and eddies plays in determining the general distribution of constituents such as ozone has long been recognized. Hemispheric differences in transport processes are particularly manifest in the formation of phenomena such as the 'Antarctic Ozone Hole' which, while primarily chemical in origin, owes much to the dynamical isolation provided by strong winter-time circumpolar vortex (section 2.5.2).

2.2 Large Scale Dynamics

Many of the features associated with the basic climatology of the large scale temperature structure of the middle atmosphere, discussed in Chapter 1, are also evident in the dynamics of this region. The satellite derived temperature climatologies have been used to produce zonally averaged winds (up to 80 km) using the geostrophic approximation (e.g. BARNETT and CORNEY, 1985). The zonal winds peak in the lower mesosphere (~ 60 km) with an eastward (westerly) flow in winter and a westward (easterly) flow in summer. A major hemispheric difference is the significantly stronger winter-time geostrophic wind in the southern hemisphere, by between 20 and 40 ms^{-1}, compared with the northern hemisphere, a feature consistent with the colder southern polar temperatures. Direct long-term measuremnets from radars in the ~20° to 70° latitude range, have given zonal and meridional winds (60-110 km) which complement the satellite data (e.g. Handbook for MAP, vol 16). Meridional velocities can only be inferred indirectly from satellite data but radar winds show long-term velocities of between 5 and 20 ms^{-1} at the mesopause region (~80-95 km altitude), generally directed from the summer to the winter pole. The meridional flow is often less steady than the zonal component.

Detailed comparisons in the overlap region (60 to ~80 km) between the geostrophic winds derived from satellite measurements and radar winds show broad agreement but some discrepancies (MANSON et al., 1987). A major difference occurs in winter where the geostrophic winds are of larger magnitude than the directly measured winds, especially in the southern hemisphere and at high latitudes. These differences have been ascribed to a variety of causes, including the inadequacy of the satellite analyses in regions where there is strong curvature of the flow associated with strong planetary wave activity. At heights above 70 km a major factor appears to be the ageostrophic nature of the winds due to the strong wave drag caused by breaking gravity waves. Winds measured directly by the UARS satellite, to be launched in the early 1990s, will give an opportunity for further comparisons. In the meantime, the new CIRA (to appear in 1990) contains gradient winds based on satellite and thermospheric model data from 20-120 km, plus global radar winds and southern hemisphere rocket-derived winds.

The presence of large-amplitude quasi-stationary waves causes considerable departures from a zonal mean structure in the winter-time stratosphere, even on a monthly mean basis. Substantial hemispheric differences are observed with the southern hemisphere showing smaller amplitude waves, which in turn leads to significant hemispheric differences in transport effects (see section 2.5). These, and other planetary-scale features such as the normal-mode oscillations in temperature noted in chapter 1, all manifest themselves in wind oscillations. A feature particularly evident in the mesospheric wind field in summer is a westward propagating, wavenumber-3 oscillation with a period near two days. Amplitudes in excess of 50 ms^{-1} have been observed in the southern hemisphere; the apparently non-linear nature of the quasi-2-day wave may cause significant transport effects of important trace species such as ozone.

2.3 Atmospheric Tides, Gravity Waves and Turbulence

Tides and gravity waves play an important role in coupling energy and momentum from the lower to the upper atmosphere. Atmospheric tides are forced by the absorption of solar radiation by tropospheric water vapour and by stratospheric ozone. Known gravity wave sources are topography, wind shears, convection, and geostrophic adjustment. The wider geographic distribution of ground-based radars, especially at mid- and high-latitudes, has resulted in steady progress in our knowledge of motions produced by these waves in the mesosphere and lower thermosphere; radars of the VHF/UHF MST type have started to provide detailed wave and turbulence information about the lower atmosphere and upward coupling of wave energy. Radars and highly detailed rocket and balloon measurements have been used to investigate turbulence. The actions of the ATMAP and GRATMAP projects of MAP and the organization of radar workshops have been especially useful in coordinating observations and standardizing data analysis techniques and presentation (see Handbooks for MAP, volumes 9, 14 and 20).

2.3.1 Atmospheric Tides

Initial results from international observational campaigns showed that comparisons between stations of tidal amplitudes and phases derived from only a few days data were difficult due to the inherent tidal variability. Much better consistency was achieved when monthly mean climatologies were used which led to the recommendation that climatologies of tidal parameters be assembled over intervals of between 10 and 30 days. Monthly climatologies have been especially successful in elucidating seasonal and inter-annual variations.

In the mesosphere at latitudes less than about 35°, the diurnal tide is characterized large amplitudes at the equinoxes, with monthly mean amplitudes of up to 40-50 ms^{-1} being observed at heights near 90 km in the southern hemisphere. Significant interhemispheric asymmetries have been found, with larger amplitudes in the southern hemisphere. These differences are possibly caused by differences in dissipation suffered by the fundamental (1,1) mode as it propagates up through the middle atmosphere (VINCENT et al., 1988). In most months at mid-, high-latitudes the tidal phases are either irregular or show little change with height, evidence for long vertical wavelengths or evanesence. Only in winter is there a tendancy for short wavelengths. Amplitudes are small (5-15 ms^{-1} at 90-95 km) with only weak seasonal variations.

From a theoretical viewpoint, there is now a better understanding of how dissipation and mean winds act on the diurnal tide (VIAL, 1986) with a combination of a distorted (1,1) mode and the (1,-2) trapped mode reproducing many of the observed features. As more realistic dissipation and background winds and temperatures are incorporated in the models it is expected that even better agreement between observations and numerical simulations will result. However, because the propagating diurnal modes are equatorially confined, it will be difficult to fully refine theory and modelling until observations from more low-latitude and equatorial sites become available. Equatorial observations will be crucial in determining the role played by the diurnal tide in the momentum and energy budgets of the upper middle atmosphere.

The degree of both observational and theoretical understanding of the semi-diurnal tide in the upper middle atmosphere is even more satisfactory. While there may be some variations between stations, most report systematic seasonal changes in amplitude and phase behaviour which are repeatable from one year to the next (e.g. TSUDA, et al., 1988). Generally, at mid-latitudes (45-55°) the tide has small amplitudes (~10-15 ms^{-1} at 90-95 km) in local summer, with long vertical wavelengths. Shorter vertical wavelengths (40-80 km) and generally larger amplitudes (~20-25 ms^{-1}) occur in winter. Rapid changes in phase and amplitude occur near the time of the zonal wind reversals at the equinoxes. Similar behaviour is shown at low and high latitudes as far as phase and wavelengths are concerned, but amplitudes are waeker and and their seasonal variations are different at low-latitudes near 90 km. Strong asymmetries are apparent when observations from stations located symmetrically about the equator are compared, which is consitent with the large seasonal variations. Numerical modelling shows that these asymmetries can be explained by modal coupling induced by the hemispheric asymmetries in the background winds of the middle atmosphere. It has now become possible to model the semi-diurnal tide on a month-by-month basis using the satellite derived wind and temperature climatologies.

Papers describing and summarizing the results of observational, modelling and theoretical studies of tides made in the past decade may found in a special issue of the Journal of Atmospheric and Terrestrial Physics, July/August, 1989.

2.3.2 Atmospheric Gravity Waves.

Observational studies have likewise contributed substantially to our understanding of gravity wave processes in the middle atmosphere. These include studies which suggest the nature of the mechanisms which act to limit wave amplitudes, the gravity wave scales responsible for a saturated wave spectrum at high vertical wavenumbers as well as the considerable geographic and temporal variability of the wave spectrum and its implied middle atmosphere effects.

Most progress has been made in the mesosphere wher the wave amplitudes are large. Climatologies of gravity wave motions show a semi-annual variation of wave amplitudes in the upper mesosphere with minimum amplitudes at the equinoxes; this variation becomes progressively less prominent in the lower thermosphere. Typical rms amplitudes are ~25–35 ms^{-1} near the mesopause. There is strong evidence for considerable short-term fluctuations in wave energy and momentum fluxes. It is believed that these quantities are very dependent on the environment through which the waves propagate, resulting in the modulation of the fluxes and their effects by larger-scale wave motions (including tides) and temporally and spatially varying mean flows. Changing source conditions are also expected to contribute to the variability of the wave spectrum and its effects. Determination of the relative importance of filtering and source effects on wave variability remains an important problem which requires further investigation.

Considerable progress has been made in addressing the propagation, dissipation and effects of internal gravity waves in the middle atmosphere (FRITTS, 1984). Both theoretical and observational studies have shown that these motions can contribute a body force or drag which produces an acceleration of ~50 $ms^{-1}day^{-1}$ in the mesosphere due to momentum flux convergence at heights at which the waves are dissipated. The drag exerted by the dissipating waves acts to close the zonal mean mesospheric jets, thus accounting for the strong meridional circulation and the reversal of the mean meridional temperature gradient near the mesopause. A similar, though less dramatic, effect is now believed to occur in the lower stratosphere as well.

A number of studies have examined the processes by which gravity waves are dissipated and the consequences of gravity wave saturation. In addition to momentum flux convergence, the principal effects of saturation are now thought to include wave amplitude limits, the prediction of large Prandtl numbers (~3-10) due to localized turbulence production and mixing and the expectation of large temporal and spatial variability of the gravity wave spectrum. Amplitude limits are believed to arise to various saturation processes and to lead to a saturated spectrum at large vertical wavenumbers, which accounts for the observed -3 slope in the logarithmic power spectrum (e.g. SMITH et al., 1987).

2.3.3 Turbulence.

The small magnitudes of turbulent motions in the middle atmosphere have made turbulence more difficult to study than gravity waves. However, one climatology of mesospheric turbulence in the 80–100 km region has been produced from ground-based observations (HOCKING, 1988). A weak semi-annual cycle in dissipation rates is evident near 80 km. High resolution spectral studies of mesospheric turbulence have been made with rocket-borne neutral gas mass-spectrometers, positive ion probes and electron density probes, which enable spatial scales as small as ~0.1 m to be resolved. The spectra have been converted energy dissipation rates and diffusion coefficients although different analysis methods can lead to different answers (LUBKEN et al, 1987) and it is apparent that further theoretical work is required in this area. The rocket observations often show a high degree of variability from one flight to the next. These variations may result from the occurrence of spatially intermittent turbulence, a factor which could account for some discrepancies which have been found from turbulence intensities inferred from simultaneous radar measurements and rocket observations. Spatial intermittence in the vertical is also a feature of high-resolution balloon soundings in the stratosphere, which show alternating layers of turbulent and near-laminar flow. Again, it has not always been possible to reconcile radar and balloon estimates of the turbulent parameters and further joint studies are required.

2.4 Geomagnetic Effects on Neutral Dynamics

Although the dynamics of the upper part of the middle atmosphere is dominated by tides and gravity waves propagating upward from below it is expected at high-latitudes that the neutral atmosphere winds will be influenced by the downward-coupling of energy from the magnetosphere. A number of investigations have attempted to study the response of the winds to changes in geomagnetic activity, but often with inconclusive results, especially at heights below 100 km (e.g. JOHNSON and LUHMANN, 1988) where the effects are weak. Howeaver, significant correlations have been found between changes in magnetic activity and the neutral motions at heights above 90 km and the coupling appears to become strong by 110 km. Further work is required to unravel the response of winds in the mesosphere and lower thermosphere to magnetospheric forcing, especially during times of very high energy input

2.5 Transport in the Middle Atmosphere.

Recent developments in dynamical theory and modelling are discussed in Chapter 4; here we focus on transport processes and transport modelling. The major conceptual advances in recent years have derived from improved understanding of stratospheric vortex erosion. This breakthrough has been particularly timely, equipping us with the conceptual tools needed to comprehend dynamical aspects of the Antarctic ozone phenomenon. On smaller scales, progress in understanding transport by gravity waves and turbulence induced by these motions has been less spectacular, but nonetheless real.

The modelling of stratospheric transport apart from phenomenological studies of short term events, focuses on two-dimensional models. The design of such models continues to evolve in response to developments in our understanding of the underlying transport processes.

2.5.1 Stratospheric Vortex Dynamics and large-scale Transport in the Stratosphere

The use by McINTYRE and PALMER (1983, 1984) of Ertel potential vorticity (EPV) on surfaces of constant potential temperature as a diagnostic of large-scale transport, and their interpretation of the dynamical processes thus revealed, have revolutionized our concepts of stratospheric dynamics. The wintertime circulation is now seen as broadly divided into two regions: (i) a "main vortex" which, though being somewhat mobile and flexible (especially in the northern hemisphere) maintains its integrity as a material entity until its demise during the final spring warming (though it may be temporarily disrupted during a midwinter "major" warming in the northern hemisphere) and (ii) a "surf zone" outside this vortex where vortex air and subtropical air is mixed quasi-horizontally (in fact quasi-isentropically) by breaking Rossby waves propagating along the vortex edge. The surf zone in fact occupies a large part of the hemisphere in northern winter but appears to be more confined to middle latitudes in the southern hemisphere winter (where the Rossby waves are less intense).

Aside from the purely dynamical implications of this picture, it has a direct bearing on our view of transport processes. To the extent that EPV acts as a tracer of air motions (and it should do so over periods of some days for which the motion will be approximately adiabatic), its evolution should be characteristic of that of other tracers such as long-lived chemicals constituents. This has been confirmed by comparison of EPV behaviour with that of ozone (LEOVY et al. 1985) and many other chemical tracers (e.g. GROSE and RUSSELL, 1984). Indeed, such has been the impact of EPV as a diagnostic air motion that, only five years after McIntyre and Palmer introduced the technique, generation of EPV maps on isentropic surfaces is now almost routine.

Only the gross, broadscale ("coarse-grain") structural features of the EPV distribution can be resolved in satellite-based stratospheric analyses. An idea of what may lie below the visible resolution limits may be seen from the high-resolution modelling study of JUCKES and McINTYRE (1987). They find, in agreement with other studies of non-linear vortices, that a large-scale but small-amplitude wave, when superposed on an otherwise circular vortex, generates an extraordinary degree of fine-scale structure in the process of cascading EPV variance down to small scales. Amongst other things, these results show how different air masses (air from within and outside the vortex) can be brought into close proximity, thus permitting chemical reactions between their chemical constituents.

2.5.2 The Antarctic.

The discovery by FARMAN et al. (1985) of the seasonal, spring depletion of ozone over Antarctica caused a flurry of scientific activity which culminated in two major campaigns in 1986 and 1987. Following these campaigns, we now have a firm basis for the belief that the depletion is a chemical loss process (see Chapter 5) which has become apparent in recent years as a result of the increasing concentration of stratospheric chlorine which in turn results from emission of chlorofluorocarbons.

Although the loss of ozone is a chemical effect, its appearance in the springtime Antarctic has much to do with the special characteristics of transport processes in the Antarctic lower stratosphere. The Antarctic polar night vortex suffers much less disruption by planetary waves than its Arctic counterpart and, in consequence, it is much more robust. In fact, the air is almost completely insulated from that outside; in the expression of JUCKES and McINTYRE (1987) it acts as a "chemical containment vessel" within which chemical reactions can destroy ozone without contamination with outside air. A related, equally important aspect is the inhibition of heat transport into the vortex. It is therefore barely warmer than would be expected for radiative equilibrium and, in the extreme cold, polar stratospheric clouds form; the cloud particles are essential to the heterogeneous reactions which "precondition" the vortex prior to sunrise.

One important unresolved question concerning the role of transport processes in this phenomenon is what has come to be known as the "dilution effect" - the reduction of the ozone column content in other regions of the southern hemisphere by transport of ozone-poor air out of the Antarctic. While, as noted above, the vortex is an isolated entity in early spring as the chemical depletion is occurring, it breaks down later in the spring during the "final warming" - the transition from winter to the summer circulation. At this time, transport of polar air at least into middle latitudes might be anticipated, and modelling studies (PRATHER and GARCIA, 1988) appear to support the notion that the observed downward trend in late spring ozone in southern middle latitudes might be evidence of such an effect.

2.5.3 Transport Modelling

Advances in the theoretical underpinning of two-dimensional (2D) transport models - which have been discussed elsewhere (e.g. TUNG 1984; MAHLMAN et al. 1984; WMO, 1986) have progressively made themselves felt in model design and formulation. Most models are now based on a "residual" or "diabatic" circulation, rather than the Eulerian circulation of the early models. They require as input the structure and intensity of this circulation and values for the "Ks" - diffusion coefficients representing eddy mixing. Estimates of the diabatic circulation can be derived from observed temperatures via a radiative calculation. Estimates of the Ks are less easy to obtain directly; PITARI and VISCONTI (1985) and PLUMB and MAHLMAN (1987) quantified these coefficients in general circulation models while NEWMAN et al. (1986) have used potential vorticity fluxes derived from routine stratospheric analyses to estimate Ks in the actual stratosphere. This latter approach offers in principle the best representation of the "real world"; however, this interpretation is clouded by questions of data quality (critical for a derived quantity such as potential vorticity) and uncertainty as to the suitability of potential vorticity as quantitative proxy for long-lived tracers. Estimates of K_{zz} representing vertical diffusion in the mesosphere (GARCIA and SOLOMON, 1985) have relied on the theory of gravity wave breaking (LINDZEN, 1981). Recent studies by HOLTON and SCHOEBERL (1988) suggest that transport in the mesosphere of long-lived tracers is dominated by meridional advection rather than by eddy diffusion.

A novel approach has been adopted by TUNG (1987), in which the diabatic circulation is first deduced from observations and then the (isentropic) diffusivity, K_{yy}, is calculated from the angular momentum budget (on the assumption that potential vorticity is transported like a long-lived tracer). This ensures that the all-important balance between advection and diffusion (see WMO, 1986) is represented in the model, and allows the model to represent the actual atmosphere on a month-to-month basis, including interannual variability.

A major use of such models is in long-term integrations, especially assessments of the future state of the atmosphere (such as ozone depletion scenarios). The inability of 2D models with fixed eddy transport to respond to climate changes is a disadvantage in such cases. An interesting way of circumventing this problem has been introduced by HITCHMANN and BRASSEUR (1988) who incorporate a simple model (using WKB theory) for the stratospheric planetary waves, thereby allowing the waves to respond to changes in, e.g. stratospheric zonal winds. It is still necessary, however, to specify the wave amplitudes at the model tropopause.

Finally we should make some comments on the status of 3D transport models. These models are basically middle atmosphere GCMs, which are discussed elsewhere in this document (See Chapter 4). Because of the computational expense of incorporating comprehensive chemistry into such models they are not at present used for long-term integration (nor are they likely to be in the near future). They are, however, being used increasingly for shorter-term experiments which enhance our ability to interpret observations of trace constituent evolution and further our understanding of transport processes (e.g. GROSE et al., 1987).

2.6 Summary and Recommendations.

(1) Our understanding of the dynamical and transport processes in the middle atmosphere have benefited greatly from satellite measurements. However, there have been constraints because wind and higher order quantities such as potential vorticity are derived from satellite observed temperatures alone. Direct satellite measurements of wind will become available when UARS is launched in the early 1990s. Every opportunity should be taken to undertake joint studies between satellite and ground based measured winds in order to maximize the information on large and small-scale dynamics, especially with a view to further delineating hemispheric differences. Continuity of observations, both satellite and ground based, is crucial for the establishment of climatologies and especially the detection of trends.

(2) Probably the least well understood region from a dynamical viewpoint is the equatorial middle atmosphere. Kelvin, Rossby-gravity and gravity waves are believed to play important roles in driving the QBO and the semi-annual oscillations in the stratosphere and mesosphere. Dissipation of the diurnal tide is also likely to be important for the momentum budget of the equatorial upper mesosphere. Equatorial waves tend to have short vertical wavelengths and while limb-viewing satellites have provided new information about the larger scale waves there is a pressing need for the deployment in equatorial regions of ground based radars and lidars with their good height and time resolutions. If possible, networks of stations are required in order to determine the wave sources.

(3) Despite the considerable progress during the MAP period, we still lack knowledge of important aspects of gravity wave propagation and dissipation in the middle atmosphere. These include the detailed mechanisms by which wave motions undergo saturation, the products of this saturation process (whether other waves/and or turbulence), the evolution of turbulence in stratified and sheared flows, and the effects of these wave and turbulence processes on the large-scale circulation and structure of the atmosphere. Height profiles of momentum fluxes are especially required.

More information is required on the geographic and temporal variability of the wave spectrum and its response to various and variable sources in the lower atmosphere. There is a need for: (i) detailed high resolution studies of wave excitation, propagation and dissipation using as wide a range of instrumentation as possible to delineate fully the wave structures and their local effects. (ii) long-term observations of wave motions and their environment at diverse geographic locations to address their statistical effects and variability.

(4) Tidal studies have made steady progress in MAP and more can be expected as the observational network expands and theory incorporates better background wind and temperature structure in the models. Nevertheless, there are a number of areas which require more attention. While the seasonal behaviour has been reasonably well documented the causes of short term variations in tidal structure are poorly understood. Possible causes are fluctuations in O_3 and H_2O in the forcing regions, and interactions between tides, gravity waves and turbulence.

The influence of non-migratory modes is poorly understood and needs further study with a network of closely spaced observatories. There have been few studies of the 8 and 6 hr tidal modes; it is possible that 8 and 6 hr oscillations may be generated by non-linear interactions between the 24 and 12 hr tides in the mesosphere and further observations are required to test this hypothesis. Similarly, apparent interactions between the 24 hr, 12 hr and quasi-2-day oscillation in local summer have been reported to produce oscillations at 16 and 9 hr, phenomena which deserve further investigation.

Tides couple significant energy amd momentum upwards into the thermosphere. It is important that there be further development, through observation and theory, of tidal descriptions in the upper middle atmosphere which can properly describe the the lower boundary of the thermosphere.

(5) The response of the neutral atmosphere at mid- and high-latitudes to changes in energy coupled downwards from the magnetosphere is still uncertain and requires further study. The apparent relationship between solar cycle variations, stratospheric warmings and the QBO will have a complex response in the middle atmosphere and needs a long-term global assessment.

CHAPTER 3

RADIATION

The major contributions to the energy balance of the middle atmosphere are the absorption of solar ultraviolet (or short-wave) radiation, especially by ozone, and the cooling to space through infrared (long-wave) radiation, principally by carbon dioxide. Local imbalances between short-wave heating and long-wave cooling provide the driving forces for dynamical processes. Much effort has been occurred in the past decade to accurately measure the solar irradiance in various wavelength bands and its variability on both short and long timescales. There has been good progress, although much remains to be done. Similarly, there has been steady progress in understanding of long-wave processes. The following sections summarize this progress.

3.1 Solar Ultraviolet Radiation

The solar electromagnetic radiation is the primary source of energy for the terrestrial environment. The largest fraction of energy associated with the solar spectrum is situated in the visible. The ultraviolet domain for wavelengths shorter than 320 nm represents only a small fraction (2 percent) of the total incident flux. This spectral range is of fundamental importance for aeronomic processes taking place in the troposphere, the middle atmosphere and the thermosphere.

Because of the complexity of the atmospheric processes and the strong interplay and feedback between transport, chemical composition and radiative budget, atmospheric and climate studies should include observations of the ultraviolet solar radiation and its variability, in close relation with the atmospheric constituent which control the penetration of solar radiation. The ozone molecule is a key minor constituent for the stratosphere by photodissociation of molecular oxygen by solar radiation of wavelengths shorter than 242nm. It provides the main heat source through the absorption of solar ultraviolet radiation and thus determines to a great extent the temperature profile in the stratosphere and the general circulation. Ozone therefore couples the stratosphere and the tropospheric climate through complex processes involving radiative, chemical and dynamical effects.

Consequently, the knowledge of solar ultraviolet irradiance values as well as their temporal variations is fundamental in studying the chemical, dynamical and radiative processes in the middle atmosphere. In addition, the study of solar variability is of crucial importance to distinguish between its impact on the terrestrial environment in comparison with anthropogenic perturbations.

During the solar cycle 21 (1975-1986), several measurements of solar ultraviolet irradiance from Lyman α to 400nm have been performed including observations from balloons, rockets, space shuttle and satellites. Many of those measurements have been reviewed by BRASSEUR and SIMON (1981), LEAN (1987), ROTTMAN (1987), SIMON (1978, 1981), and SIMON and BRASSEUR (1983). In addition, two WMO-NASA assessment reports on stratospheric ozone (WMO, 1982; WMO, 1986) have been published, including solar ultraviolet radiation discussions relevant to stratospheric ozone.

Variations of solar ultraviolet irradiance have also been analyzed in the same aforementioned works. More recently, new insights on the temporal variability of ultraviolet solar irradiance has been provided by DONNELLY (1988) using data acquired by the Solar Backscatter Ultraviolet (SBUV) spectrometer on board Nimbus 7 and by ROTTMAN (1989) for the data taken by the Solar Mesosphere Explorer (SME) satellite.

The following sections summarize the major findings concerning the absolute values of irradiance in wavelength bands from Lyman α to 320nm, and the temporal variabilities related to the 11-year solar activity cycle and the 27-day modulation, based on the observations obtained during the solar cycle 21.

3.2. The HI Lyman α Emission Line (121.6 nm)

The Lyman α solar chromospheric line initiates photoionization processes in the D-region and the photodissociation, for instance, of water vapor in the mesosphere, controlling the ozone budget in the mesosphere through the production of hydroxyl radicals. Two data sets have been obtained by satellite, namely the Atmospheric Explorer-E (AE-E) and SME, respectively from June 1977 to May 1980 during the rising phase of the solar cycle 21 and since January 1982 corresponding to the declining phase of the same cycle. Additional 'snapshot' observations of Lyman α obtained by rockets and Spacelab 2 are listed in Table 3.1.

Although some values are close to 2×10^{11} $h\nu.s^{-1}$ cm^{-2} during the minimum of activity between solar cycle 20 and 21, the average value of the rocket measurements made between December 1972 and March 1977 is 3×10^{11} $h\nu.s^{-1}.cm^{-2}$. This value has been widely adopted for low solar activity condition. It has even been used as a minimum value (mid 1976) to normalize the AE-E time series. Nevertheless, the Solar Ultraviolet Spectral Irradiance Monitor (SUSIM) observation which took place in August 1985 during the most recent minimum of activity gives a relatively high value of 3.79×10^{11} $h\nu.s^{-1}.cm^{-2}$, that is to say 26 percent above the conventional value adopted for minimum level of activity. However, a result quite contrary to the SUSIM value is obtained by the SME time series calibrated with a rocket observation performed on May 17, 1982 (MOUNT and ROTTMAN, 1983a) which gave minimum values around 2.5×10^{11} $h\nu.s^{-1}.cm^{-2}$ in 1986.

On the other hand, the 11-year variation range is also still uncertain. Most of the observations suggest a factor of 2 for variation over one solar cycle, except for the AE-E time series which indicates a factor of 3 but which display unexplained shifts in measured radiances for several solar emission lines. This phenomena led to criticisms of the AE-E measurements (BOSSY and NICOLET, 1982; BOSSY, 1983; OSTER, 1983). However, arguments in favor of AE-E Lyman α time series have also been reported by DONNELLY et al. (1986) and DONNELLY (1987). Recent analysis of the SME time series gives a variation factor of only 1.68 from January 1982 to mid 1986.

Hence, the absolute minimum value of irradiance as well as long-term variations on the activity cycle are still subject to controversy, although the reliability of SME data favors a minimum value around 2.5×10^{11} $h\nu s^{-1}cm^{-2}$ and a solar cycle variation of radiation less than a factor of two. This conclusion is supported by other studies, for instance, the data obtained by the Pioneer Venus Orbiter, suggesting a solar cycle variation of 1.8 (AJELLO et al., 1987).

The 27-day variations are well determined with the recent analysis of the SME time series since 1982 reported by SIMON et al. (1987) (see 3.6.1). This relatively large rotation effect must be considered when comparing snapshot measurements. This variation can occassionally reach a maximum of 30 percent (peak-to-peak amplitude) for the strongest 27-day modulation (e.g. August 1982) but is lower than 10 percent for a quiet Sun.

TABLE 3.2. Integrated solar irradiance values between 135 and 175 nm observed since December 1972.

Date	Radio flux at 1 AU (10.7 cm) +	Irradiance $10^{11} h\nu . s^{-1} . cm^{-2}$	Accuracy percent	Reference
Dec 13 1972	111	8.7	± 27	ROTTMAN (1981)
Aug 30 1973	101	7.7	± 24	ROTTMAN (1981)
Nov 02 1973	84	5.7	± 20	HEROUX and HIGGINS (1977)
Apr 23 1974	74	5.2	± 20	HEROUX and HIGGENS (1977)
Jul 28 1975	76	8.2	± 24	ROTTMAN (1981)
Feb 18 1976	70	10.0	± 24	ROTTMAN (1981)
Mar 09 1977	80	10.0	± 24	ROTTMAN (1981)
Nov 16 1978	129	(8.0)*	± 8	MENTALL et al., (1985)
Jun 05 1979	230	15.0	± 12	MOUNT et al., (1980)
May 22 1980	277	(8.4)*	± 13	MENTALL et al., (1985)
Jul 15 1980	218	14.0	± 13	MOUNT and ROTTMAN (1983a)
Oct 16 1981	303	(6.7)*	± 5	MENTALL et al., (1985)
May 17 1982	142	8.0	± 8	MOUNT and ROTTMAN (1983a)
Jul 25 1983	137	7.2	± 8	MOUNT and ROTTMAN (1985)
AUG 3 1985	79	12.5	±3.5	VANHOOSIER and BRUECKNER (1987) SUSIM, Spacelab 2

* From NICOLET and KENNES (1988)

Actually, values for wavelengths below 150nm were not published by MENTALL et al (1985).

+ unit: 10^{-22} W.m^{-2} .Hz^{-1}.

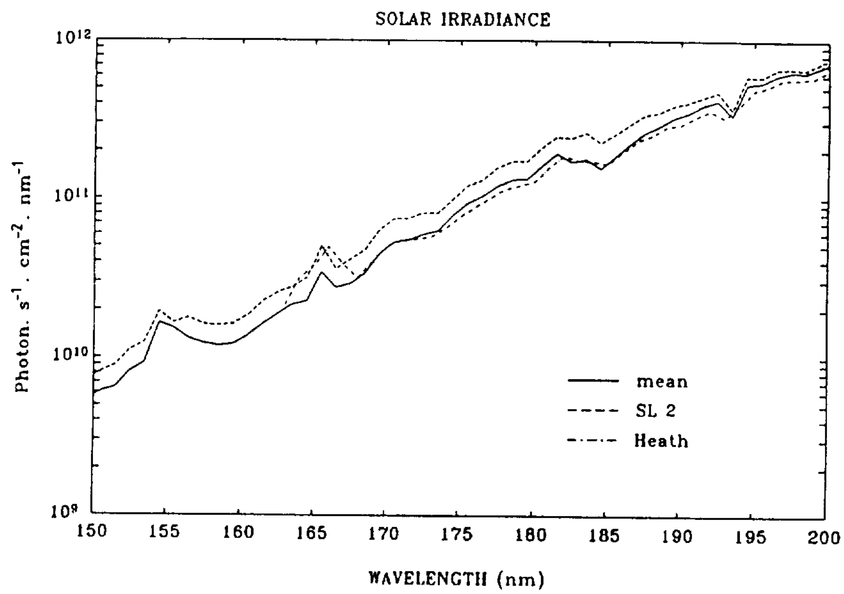


Figure 3.1 Comparison of solar ultraviolet irradiance integrated over 1nm between 150 and 200 nm. The solid curve represents the average 4 rocket observations performed between May 1982 and December 1984 (see Table 3). The dashed curve represents the data obtained from the Spacelab 2 (SL2) mission in August 1985 and the dot-dashed curve, the data reported by HEATH (1980) obtained on November 7, 1978 by SBUV.

TABLE 3.3

Integrated solar irradiance values between 175 and 200 nm observed during the solar cycle 21, by means of rocket, satellite and space shuttle.

	Integrated irradiance (accuracy) 10^{-11} h.s^{-1}.cm^{-2} (percent)			Solar Radio Flux 10^{-22} W·m^{-2}. Hz^{-1} (1AU)	
	275 - 180 nm	180 - 190 nm	190 - 200 nm	10.7 cm	Reference
Nov. 07, 1978	5.23 (± 10%)	20.4 (± 10%)	46.00 (± 10%)	175	Heath (1980) SBUV, Nimbus 7
July 15, 1980	7.17 (± 10%)	22.8 (± 16%)	49.2 (± 16%)	218	Mount and Rottman (1983a)
Oct. 16, 1981	5.62 (± 5%)	23.1 (± 18%)	44.4 (± 18%)	303	Mentall et al. (1985)
May 17, 1982	6.37 (± 8%)	20.9 (± 8%)	50.7 (± 8%)	142	Mount and Rottman (1983a)
Jan 12, 1983		21.1 (± 20%)	52.5 (± 20%)	136	Mount and Rottman (1983b)
July 25, 1983	5.73 (± 15%)	20.3 (± 8%)	50.4 (± 8%)	137	Mount and Rottman (1985)
Dec. 07, 1983	5.73 (± 8%)	22.5 (± 9%)	51.4 (± 8%)	99	Mentall and Williams (1988)
Dec. 10, 1984	5.44 (± 4%)	21.8 (± 9%)	51.8 (± 8%)	76	Mentall and Williams (1988)
Aug. 03, 1985	7.69 (± 3.5%)	28.2 (± 3.5%)	57.1 (± 3.5%)	79	Van Hoosier and Brueckner (1987), SUSIM, Spacelab 2

*Wavelength range of measured irradiance values starting at 180 nm difficult instrument calibration in this spectral range (see references listed in Table 3.3). Indeed, since the sensitivities of the two spectrometers needed to cover that spectral region are rapidly changing with wavelength, their individual calibrations are more difficult and require, in some cases, different radiometric standards. MENTALL and WILLIAMS (1988) attempt to solve this problem by using a third midrange spectrometer providing additional coverage in the overlap region (180-190 nm) of the two other instruments.

In conclusion, the absolute value of solar irradiance in the 175-200 wavelength remains very uncertain and needs further dedicated observations in order to determine accurate irradiance values for low and high activity condition.

3.5. The 200-320nm Interval

This spectral region is of particular interest for the stratosphere and the troposphere. Irradiance at wavelengths up to 240nm are responsible for ozone production in the stratosphere. The 280-320nm interval (UV-B) is also of fundamental importance for the tropospheric chemistry.

The 200-300 nm interval has been extensively discussed by LABS et al. (1987) when they reported the recent data obtained from the Spacelab 1 mission in December 1983. From their comparison with previous data it appears that the new data harmonize better with the spectral distributions of HEATH (1980) and MENTALL et al. (1981) than those reported by MOUNT and ROTTMAN (1983a, 1983b, 1985). However, all absolute values agree within +5 and -10 percent.

The most recent observations, performed during the Spacelab 2 mission by means of the SUSIM experiment and reported by VANHOOSIER and BRUECKNER (1987), are in very good agreement with the Spacelab 1 data beyond 220nm, namely within ±2 percent, but diverge by 14 percent at 200nm. The comparison of the Spacelab 1 data with those of MENTALL and WILLIAMS, (1988) obtained by rocket gives divergences up to 11 percent at 200nm but decreases to less than 4 percent between 260 and 310nm. It should bepointed out that the new rocket measurements refer to identical spectrometers and to similar calibration procedures traceable to the NBS radiometric scale. The average spectrum is given in Figure 3.2.

The ratios of irradiances referred to the Spacelab 1 data are presented in Figure 3.3 for the different observations. As far as the absolute value is concerned, nearly all values agree within ± 10 percent. The quoted accuracy of the Spacelab 1 and Spacelab 2 observations are respectively 5.2 percent and 3.5 percent.

3.6. Temporal Variations of Solar Ultraviolet

The ultraviolet range of the solar electromagnetic spectrum is characterized by its temporal variations which directly affect the atmosphere. Two time scales are generally considered in relation with aeronomic studies of the middle atmosphere: the 11-year activity cycle and the 27-day rotation period of the Sun. At present, effects of long-term variation of solar ultraviolet irradiance are not conclusive because observations of changes on that time scale in both the ultraviolet solar flux and the sensitive trace species are not reliable at the level of natural changes.

Because of the difficulty in detecting the solar irradiance variation related to the solar activity cycle, the impact of the 27-day variation associated with the rotation period of the Sun was analyzed in detail. Indeed, observations over short scale periods are far more accurate in that they avoid the aging

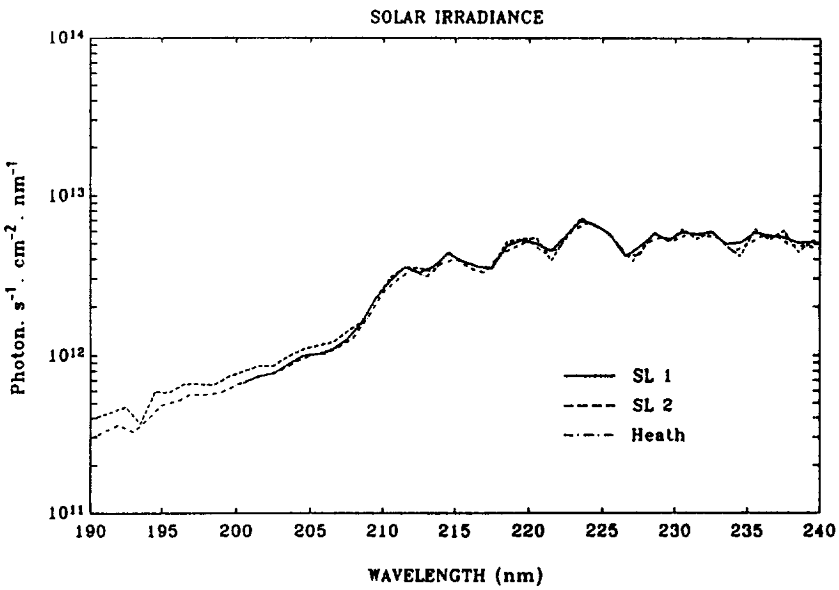


Figure 3.2 Comparison of solar ultraviolet irradiance integrated over 1nm between 190 and 240 nm. The solid curve represents the data obtained from the Spacelab 1 (SL1) mission in December 1984. The dashed curve represents the data obtained from the Spacelab 2 (SL2) mission in August 1985, and the dot-dashed curve, the data reported by HEATH (1980) obtained on November 7, 1978 from SBUV.

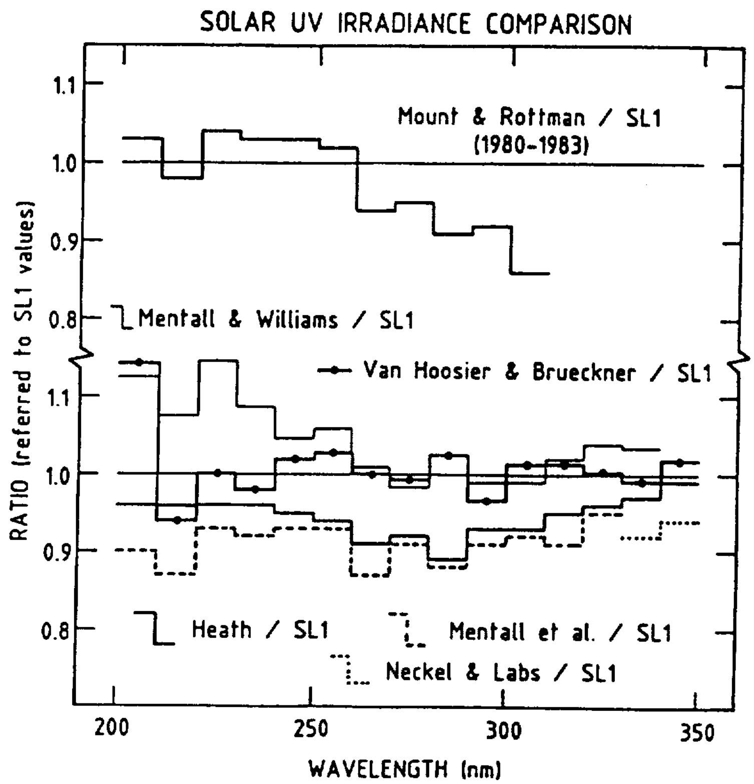


Figure 3.3 Comparison of 10 nm spectral averages of solar irradiances measurements between 200 and 350 nm with the Spacelab 1 (SL1) results (adapted from LABS et al., 1987).

problem of the observing instrumentation. These studies are very useful in the validation of photochemical processes.

3.6.1 The 27-Day Variations

The 27-day solar rotation variations have been well documented with the SBUV satellite and the SME data base. The analysis of solar-rotation induced variations from the SBUV observations has been recently reported by Donnelly (1988) showing great uniformity in the shape of this modulation during the six years of observation from November 7, 1978 to October 29, 1984 for wavelengths between 175 and 285nm. Several examples of variations in that spectral region have been published by HEATH and SCHLESINGER (1986). The strongest modulation occurred in August 1982, giving a variation of 6 percent at 205 nm.

The SME data base has also been extensively analyzed using the Fast Fourier Transform technique (FFT) to isolate the solar flux modulation related to the 27-day solar rotation. The amplitude variations over the full spectral range, namely 115-300nm, have been deduced for five years of observation from January 1, 1982 to December 31, 1986. The first results of this analysis have been reported by SIMON et al. (1987). An example of the temporal variations of the peak-to-peak amplitude for modulation at Lyman α and 205nm is presented in Figure 3.4. These 27-day modulations show periods of high uniformity in shape as, for example, in mid-1982. On the other hand, other periods show striking differences in shape for those two wavelengths as, for instance, in mid-1983 and the beginning of 1984.

The same technique has been applied to the SBUV time series for comparison purposes. The agreement between the two satellites during the overlapping period of time is very good for the strongest modulation which took place in August 1982 as illustrated in Figure 3.5. However, the average during the declining phase of the solar cycle shows some appreciable differences beyond 240nm where SBUV data are less noisy than those of SME and below 190nm where SME give higher 27-day variations than SBUV, especially for the Si II lines. The agreement is very good for wavelengths between 210 and 230nm. The best description of the 27-day variations during the declining phase of solar cycle 21 would be provided by the SME data base from 115 to 210 and from the SBUV observation from 210 to 300nm.

3.6.2. Solar Cycle Variations

Despite of considerable observational effort during the last cycle, the amplitude of solar variation associated with the 11-year activity cycle is still uncertain. The SBUV spectrometer suffered from severe aging problems, mainly in the reflectivity of the diffuser plate used for solar irradiance measurements. The available data have been accordingly corrected for instrument related changes (DONNELLY, 1988) and were analyzed by HEATH and SCHLESINGER (1986). They deduced long-term variations from an empirical relation based on temporal variation of ratios between core and wings irradiances of the Mg II lines at 280nm. This study is intended to eliminate the effects of instrumental drift and defines the so-called Mg II index. Balloon measurements at high resolution reported by HALL and ANDERSON (1988) demonstrate that the value of the Mg II index is very sensitive to unique instruments characteristics (spectral bandpass and line shape). Consequently, the extension of this index to other data sets has to be made very carefully and requires a critical normalization with data overlapping in time with SBUV observations. On the other hand, the amplitude of the solar cycle variations deduced from the Mg II index are not fully confirmed by the SME results obtained during the declining phase of solar cycle 21 (since 1982) which lead to lower values in the overlapping wavelength range (160-300nm). In addition, long-term variations

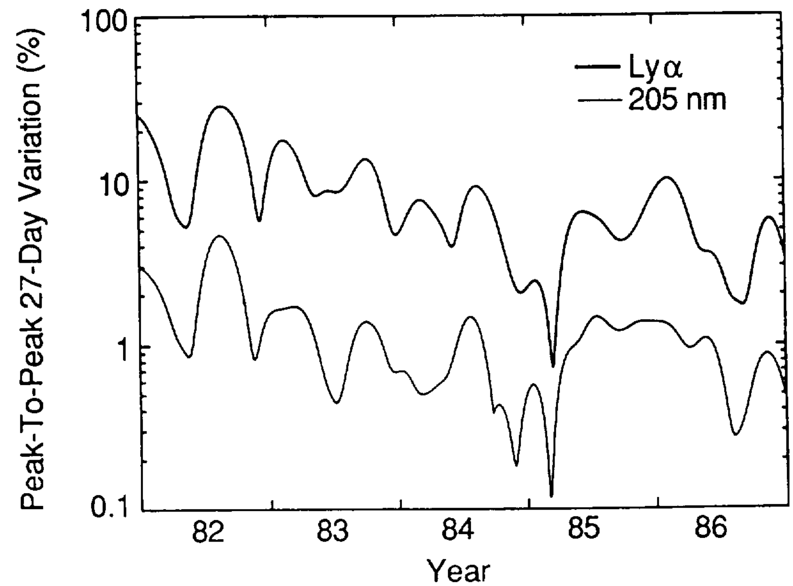


Figure 3.4 Temporal variations, deduced from a FFT analysis of the SME data of the 27-day peak-to-peak amplitude of the solar-rotation induced modulation between January 1982 and December 1986, at 2 wavelengths, namely Lyman α (thick curve) and 205nm (thin curve).

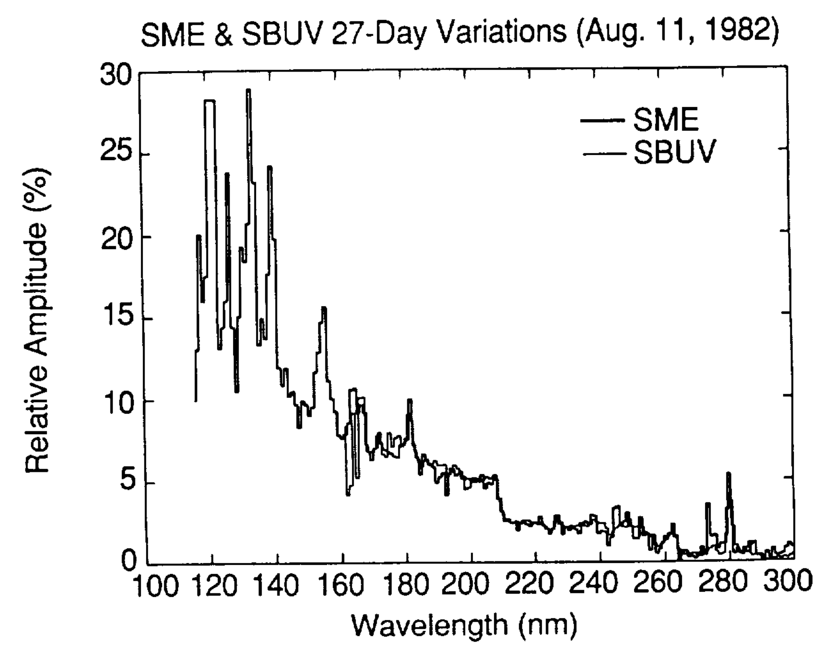


Figure 3.5 Comparison of the peak-to-peak amplitude for the 27-day variation deduced from SME (thick curve) and SBUV (thin curve) observations as a function of wavelength for 1nm intervals, for a major variation on August 11, 1982.

between 115 and 180nm deduced by comparison between rocket observations made during maximum levels of solar activity, namely 1979 and 1980 (MOUNT et al., 1980; MOUNT and ROTTMAN, 1981) and those performed at solar minimum (ROTTMAN, 1981), were of the order of 2 for Lyman α, as well as around a wavelength of 150nm. These high values are not supported by recent analysis of SME data, which imply variations of only 15 percent around 150nm and of 5 percent between 180 and 210nm (Figure 3.6).

3.7. Conclusions

Knowledge of solar ultraviolet irradiance was very poor until 1981. Uncertainties in observations varied between 10 and 20 percent for most of the published irradiance measurements performed from space (SIMON, 1978; SIMON, 1981). In addition, their divergencies were larger than the quoted accuracies and much larger than the accuracies of calibration sources used at that time.

Considering that radiometric transfer sources available in 1980 had uncertainties varying from about 6 percent near 165nm to 3 percent near 400nm, the accuracies of solar irradiances measurements were expected to be in the same range. The discrepancies at that time between the accuracy goals and the achieved uncertainties for the data actually approached factors of 2 to 7 depending upon wavelength range and instrumentation. At that time, the Synchroton Users Radiation Facility (SURF) was not yet used for the calibration of published solar irradiance observations. More recent rocket observations obtained during the 1980s by the Goddard Space Flight Center (GSFC) and the Laboratory for Atmospheric and Space Physics (LASP) have been calibrated by using the NBS SURF radiometric standard. This important step forward in the calibration procedure immediately reduced the data uncertainties to ±8 percent (see the error budget in MOUNT and ROTTMAN, 1983a).

On the other hand, in-flight calibration sources have been developed for the Spacelab 1 and 2 experiments, namely the "Solar Spectrum" and "Solar Ultraviolet Spectral Irradiance Monitor" (SUSIM). They have reported new data referenced respectively to the black body of the Heidelberg Observatory (LABS et al., 1987) and to the SURF (VANHOOSIER and BRUECKNER, 1987). Irradiance values are now available with an accuracy from 3.5 percent (SUSIM) to 5.2 percent (Solar Spectrum).

In spite of the improvements in calibration procedures, important discrepancies persist between recent irradiance measurements in the spectral range between Lyman α and 200nm. This fact is probably explained by experimental problems encountered in that spectral domain. Basic questions, for instance the minimum value of Lyman α irradiance, still need to be correctly addressed in the next decade.

If the 27-day variations are well documented with the SBUV and SME observations during the solar cycle 21, the long-term variations related to the solar activity still remain uncertain. This is due to large differences between many measurements performed from 1977 to 1985. Nevertheless, good arguments now seem to validate the proposed solar cycle variation deduced from SME. This problem is of fundamental importance in ozone trend studies. Indeed, predictions in total ozone changes during the current solar cycle (its maximum of activity being expected in 1991) give an increase of ozone towards a maximum at that time. This means that the solar cycle variation in ultraviolet irradiance will counterbalance the predicted decrease due to anthropogenic chlorine compound emissions. After 1991, the total ozone column is predicted to decrease again with a rate still enhanced by the decline in solar ultraviolet irradiance. Consequently, reliable observations of solar variation with a precision of 1

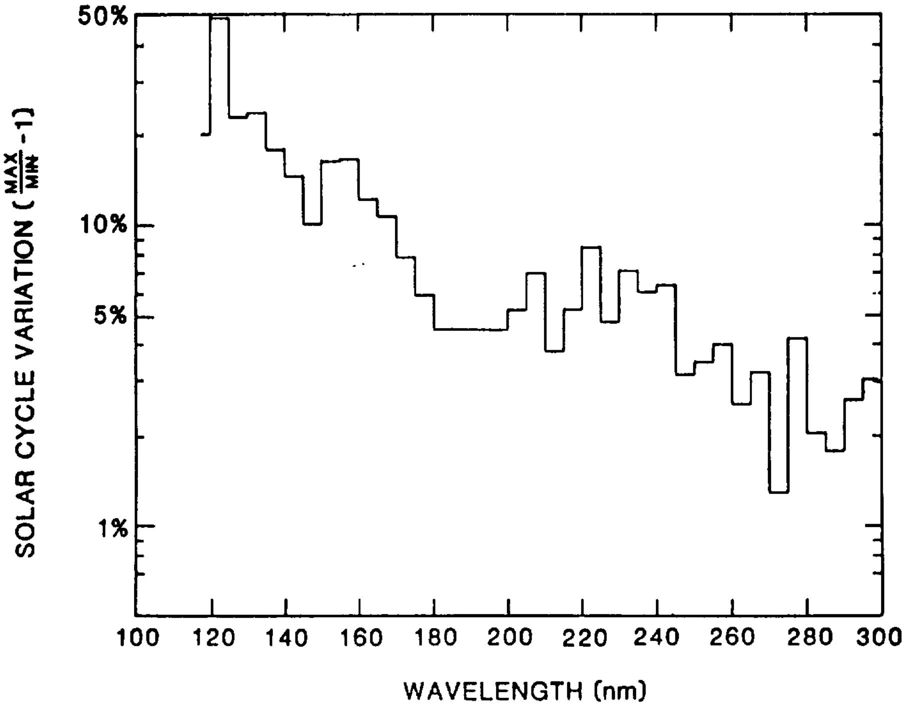


Figure 3.6 Preliminary solar cycle variation between 1982 and 1985 deduced from the SME measurements integrated over 5nm intervals between 125 and 300nm (1nm intervals). Error bars might be as large as a factor of 2 beyond 200nm (from ROTTMAN, 1989).

percent over a half solar cycle are urgently needed to quantitatively discriminate between natural changes and anthropogenic perturbations in the middle atmosphere composition.

3.8 The Role of Longwave Radiative Processes

Longwave radiation is generally defined as that part of the electromagnetic spectrum lying between 4 and approximately 200 microns. The most radiatively active atmospheric constituents for this part of the spectrum are carbon dioxide, ozone, and water vapor. In the middle atmosphere, these gases contribute to a net cooling. The longwave radiative cooling process differs from the shortwave radiative process in two important ways. First, the cooling at a particular altitude depends upon the exchange of radiation with the atmospheric layers both above and below this region. Thus, longwave cooling is coupled to regions far from the point of interest. Second, longwave cooling depends strongly on the atmospheric temperature. These two unique aspects of the longwave cooling process lead to a number of important consequences for middle atmosphere research. In particular, the temperature dependence implies that longwave cooling acts as a damping agent to temperature deviations. Thus, longwave cooling is an important dissapative source in the middle atmosphere. Secondly, the exchange aspect of longwave cooling implies that coupling between the upper troposphere and the lower stratosphere can be important. Coupling of the mesosphere to the stratosphere can also occur through this exchange of radiation.

To gain insight into the required accuracy of longwave cooling rates in the stratosphere, two factors can be considered. First, the error of the thermal structure, ΔT, of the stratosphere can be related to uncertainties in the net radiative cooling, ΔQ, through (FELS et al., 1980).

$$\Delta T = \tau_r \, \Delta Q$$

where τ_r is the radiative relaxation time in days. For the upper stratosphere τ_r is approximately 5 days, while in the lower stratosphere it can be as large as 80 days. If it is assumed that errors in longwave cooling dominate the uncertainties in the solar heating, then errors in the temperature field of less than 5K require an accuracy in the longwave cooling rate in the upper stratosphere of around 1 K day^{-1} and less than 0.07 K day^{-1} in the lower stratosphere! This example sensitivity of the lower stratosphere to errors in radiative cooling. As it turns out the contribution of each gas to the cooling in the lower stratosphere is small, and hence each component of the total cooling rate must be calculated to great accuracy.

Another way to estimate the required accuracy of radiative cooling rates in the middle atmosphere is to consider the problem of transport of chemical species. Assuming the true Lagrangian circulation can be represented by the transformed Eularian mean (TEM) circulation (DUNKERTON, 1978). The TEM vertical velocity is,

$$\bar{w}^* = \frac{Q}{N^2 H R^{-1}}$$

where N^2 is the square of the buoyancy frequency, H is the scale height, R is the gas constant, and Q is the net radiative cooling in K day^{-1}. Typical middle atmosphere values for these constants yield.

$$w^* = 0.1 \; Q \; cm \; s^{-1}$$

Once again it is assumed that the largest errors arise from longwave process. Vertical velocities in the lower stratosphere are less than 0.05 cm s^{-1} (SOLOMON et al., 1986). Thus, if the required accuracy in the vertical velocity is to be less than 0.02 cm s^{-1} for the lower stratosphere, than the cooling rates must be known to better than 0.2 K day^{-1}.

These estimates indicate that more accuracy is required in the lower stratosphere than in the upper stratosphere. Unfortunately, this is exactly the region of the stratosphere where cooling rates are most difficult to calculate. This is mainly due to the fact that each gas contributes a small and equal magnitude effect to the total cooling; and that exchange with the troposphere plays a major role in the cooling of the lower stratosphere.

The calculation of mesospheric cooling rates is dominated by two additional complications. First, pressures are sufficiently low that collisionally broadend lines (i.e. Lorentzian lines) are replaced by a Voigt line shape. Fast and accurate evaluations of the Voigt line profile are thus required for cooling rate calculations. More importantly, at altitudes above approximately 75km, non-local thermodynamic equilibrium (NLTE) becomes evident. This arises because of fewer collisions between molecules than occur at lower altitudes. With fewer collisions available to de-excite the molecules, other processes of de-excitation must be considered. Account must be taken of exchange of energy with other molecules or isotopes of the same molecule. Solution of the mesospheric cooling rates, therefore, depends on knowledge of not only spectroscopic line parameters of a given molecule, but of energy transfer rates between one type of molecule and surrounding species.

3.9 Advances in Middle Atmosphere Longwave Radiation

Over the past decade a number of advances have occurred in our understanding of middle atmosphere longwave radiation processes. These include: diagnostic studies of the radiative balance of the middle atmosphere, benchmark line-by-line cooling rate calculations, the effects of cirrus and polar stratospheric clouds on stratospheric radiative cooling, and more detailed budget studies of the mesosphere.

Diagnostic studies of the radiative balance of the middle atmosphere employ observed profiles of temperature, ozone and water vapor in conjunction with detailed radiation models. A number of studies on the radiative budget have appeared in the last 2 years (KIEHL and SOLOMON, 1986, GILLE and LYJAK, 1986, ROSENFIELD et al., 1987, CALLIS et al., 1987). These studies have used differing input data sources and radiation models. Thus, it is no surprise that important differences do exist among the studies. Results from one of these studies (KIEHL and SOLOMON, 1986) are used to indicate the relative contribution of the various gases to the longwave cooling of the middle atmosphere (see figure 3.7a-c). Carbon dioxide is the major contributor to longwave cooling. Ozone cools the upper stratosphere, but actually warms the lower tropical stratosphere. This warming results from the exchange of radiation between the troposphere and the lower stratosphere. Water vapor contributes a non-negligible cooling of 1 K day^{-1} near the summer stratopause region. The total longwave cooling is shown in figure 3.8. It is important to note that a number of other CO_2 bands contribute to the net cooling of the middle atmosphere. Additional cooling also arises from trace gases such as methane and nitrous oxide.

Over the last 4 years an intercomparison of radiation codes used in climate models (ICRCCM) has taken place. A number of line-by-line model calculations were performed for this intercomparison. Unfortunately, the profiles used for these studies emphasized the troposphere. However, accurate estimates of stratospheric cooling rates are available from the line-by-line community for a small set of profiles. These line-by-line cooling rates now provide benchmarks

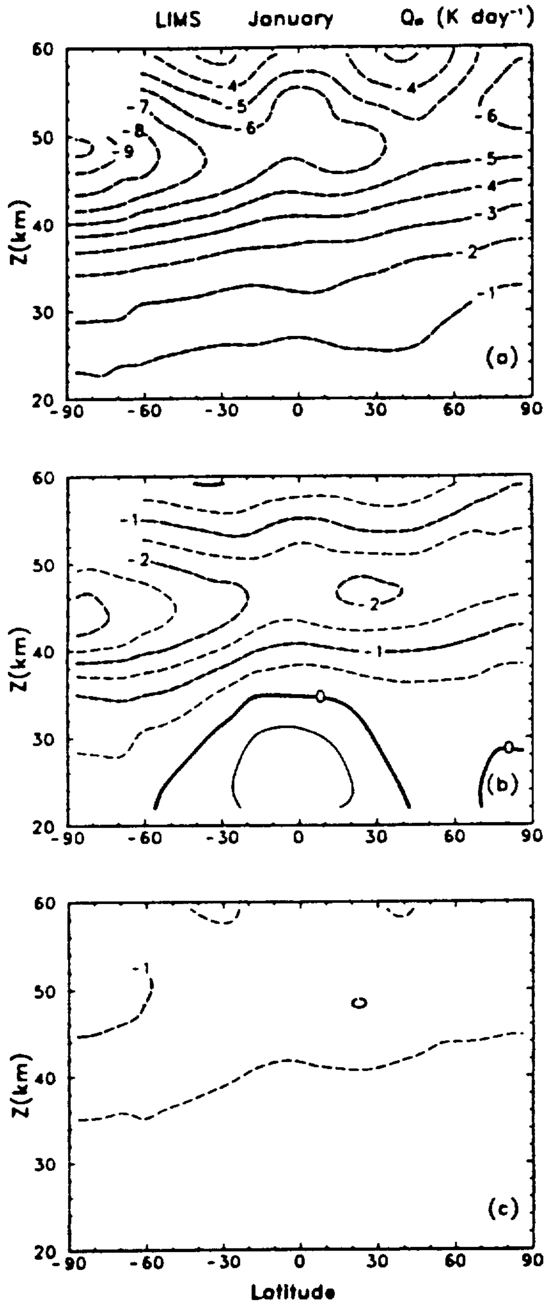


Figure 3.7 Longwave cooling due to CO_2 a), O_3 b) and H_2O c) from KIEHL and SOLOMON (1986)

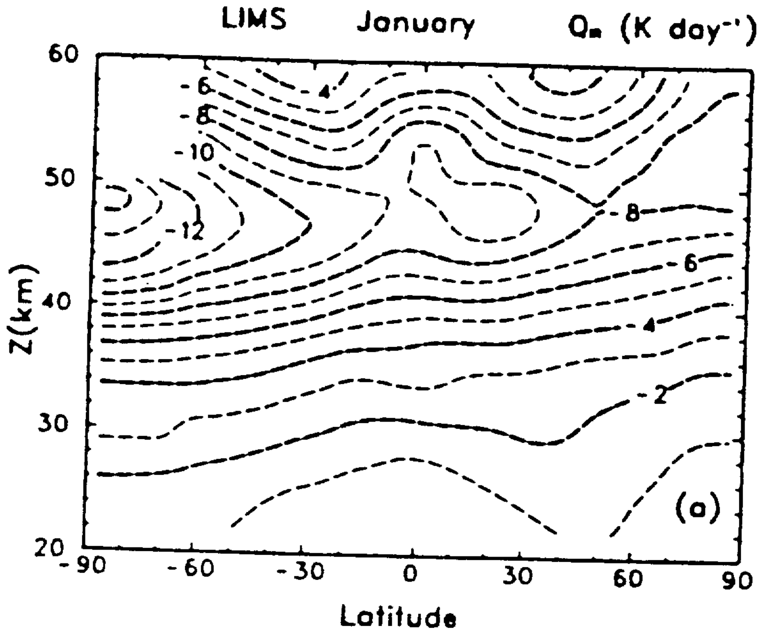


Figure 3.8 Total longwave cooling due to all gases from KIEHL and SOLOMON (1986).

to compare more parameterized models of the longwave radiative transfer process.

As noted in figure 3.7c there is a significant coupling of the tropical troposphere to the lower stratosphere. The presence of cirrus clouds can alter to a large extent the amount of longwave radiation exiting the troposphere and entering the lower stratosphere. For example, the presence of high cirrus clouds can increase the cooling of the lower stratosphere by 0.2 K day^{-1}. This is a significant change since it is of the same order as the estimates of acceptable error for this region of the middle atmosphere. Polar stratospheric clouds are now viewed as important to the chemical processes in the stratosphere. It is not clear at present whether they also play a non-negligible role in the radiative budget of the polar lower stratosphere. The damping properties of longwave radiation in the stratosphere and the mesosphere have more recently been studied by FELS (1982, 1984), respectively. These studies provide simple parameterizations of the damping rate as a function of the altitude and vertical scale of the temperature perturbation. Results for the stratosphere are shown in figure 3.9. It is apparent that for the middle and upper stratosphere damping rates are strongly scale dependent for the shorter scale waves (~6 to 12km). Since waves of this scale are known to exist in the equatorial middle atmosphere it is important that this scale dependence be accounted for in studies of their vertical propagation in the middle atmosphere.

The past 10 years has also witnessed advances in mesospheric longwave radiation studies. DICKINSON (1984, 1986) has discussed the major problems facing this field of research. Figure 3.10 shows longwave rates (DICKINSON, 1984) for the middle stratosphere through the mesosphere. The most difficult region to model lies between 70 and 90km. It is in this region that the cooling rates are strongly influenced by exchange with layers above and below. A significant amount of exchange takes place in the isotopic and hot bands of the CO_2 molecule. The importance of exchange for the fundamental CO_2 band is indicated in figure 3.11 where the ratio of layer exchange to cool-to-space contributions to the longwave cooling are shown. Note in particular the extreme importance of the exchange process for the summer mesopause region. Above 80km the cooling by CO_2 depends on the reaction of CO_2 with molecular oxygen. The reaction rate for this process is currently poorly known at present. Until this reaction rate is measured to higher accuracy, cooling above 80km will remain largely uncertain.

Recommendations

(1) Most of the solar ultraviolet radiation is absorbed in the middle atmosphere and the structure of this region is very sensitive to small changes in solar output. It is crucial that measurements of absolute values of irradiance are addressed. Measurements with a precision of 1 percent over a solar cycle are urgently needed in order to resolve the origins of change caused by natural and anthropenic perturbations of the middle atmosphere.

(2) A global compilation of temperatures, ozone amounts and water vapor mixing ratios for the middle atmosphere are required for future radiative balance studies. Along with this, more information on the height and extent of tropical cirrus clouds is required for accurate estimates of the radiative budget of the lower stratosphere. Needed also are the radiative properties of the cirrus clouds.

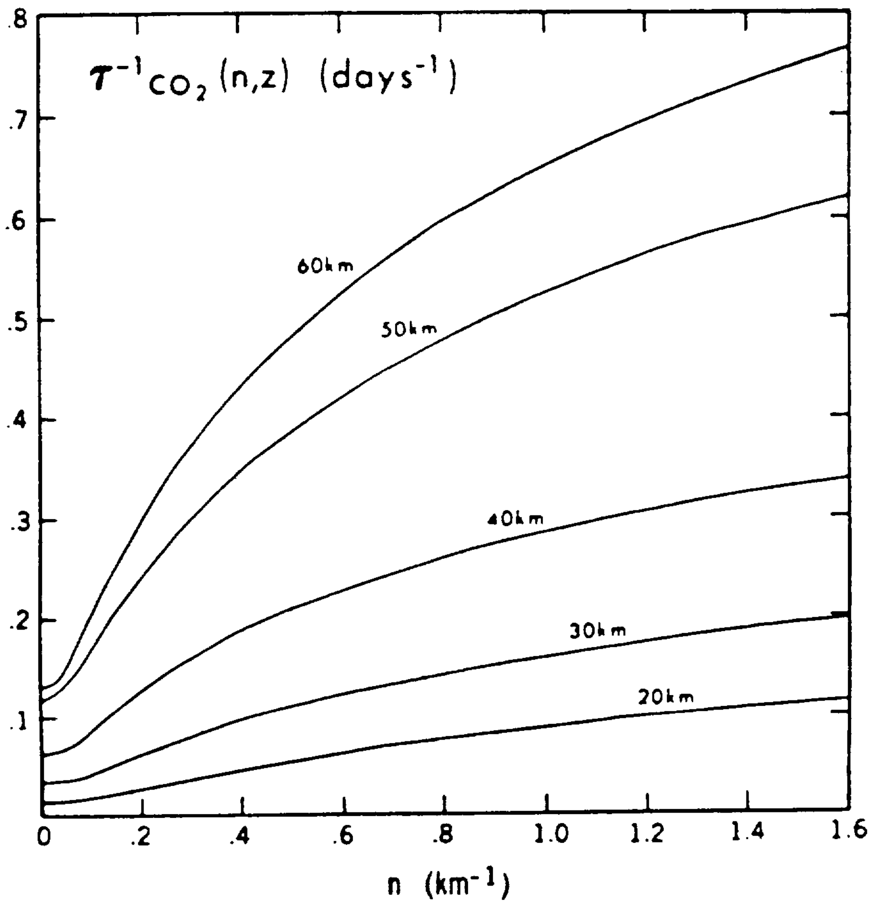


Figure 3.9 Scale dependent damping rates due to CO_2 radiative cooling from FELS (1982).

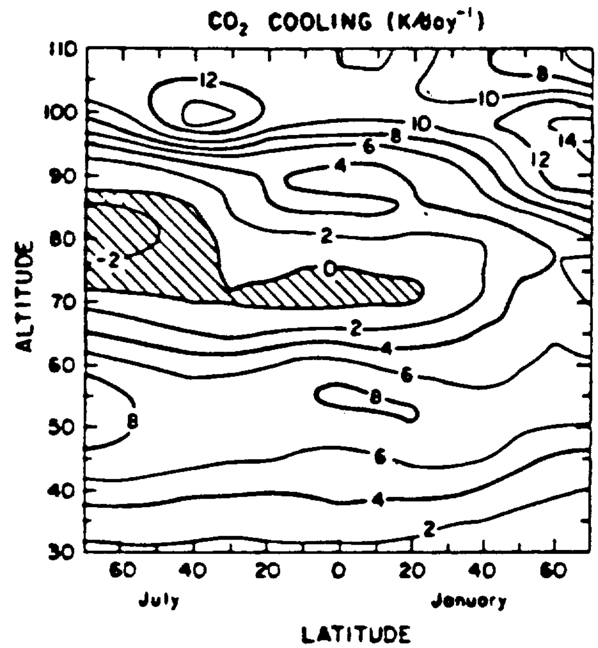


Figure 3.10 Mesospheric cooling rates calculated by DICKINSON (1984). NLTE effects are accounted for in the cooling.

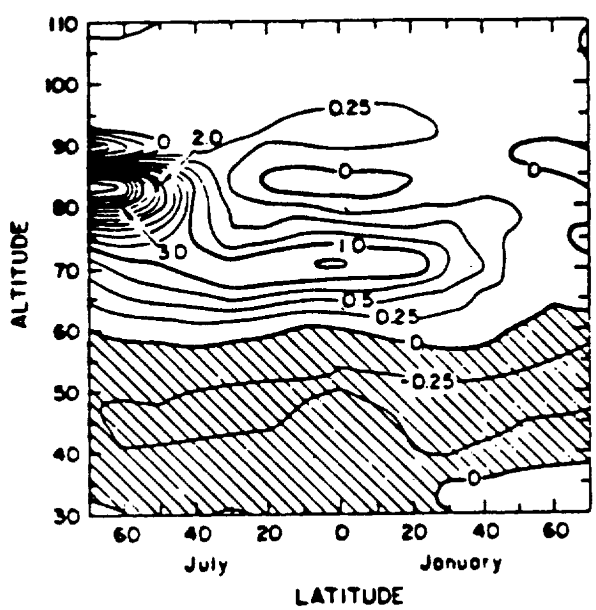


Figure 3.11 Ratio of cooling due to exchange processes to cool-to-space cooling. Results are from DICKINSON (1984).

(3) A more comprehensive set of line-by-line calculations for middle atmospheric cooling rates is needed. Also, a detailed calculation of the radiative contribution of trace gases and minor bands of CO_2 and O_3 are needed.

(4) The radiative effects of polar stratospheric clouds must be studied in greater detail. The importance of these clouds to chemical reactions is now recognized. Their radiative role remains undefined at present.

(5) More detailed knowledge of spectral line shapes and their temperature dependence is required. This is required especially for CO_2, where the line shape is known to deviate from the Lorentzian shape in the far wings.

(6) Radiative cooling rate calculations in the upper mesosphere require a more accurate determination of the reaction between CO_2 and molecular oxygen. Laboratory studies should be carried out that better define this rate.

CHAPTER 4

THEORY AND MODELS

4.1 Introduction

During the last ten years there has been steady progress, on a broad front, in the development of theories and models of the middle atmosphere. It is now clear that models are essential for the interpretation of observational data and for the understanding of the fundamental processes controlling the middle atmosphere, as well as for the prediction of its future behaviour.

Ideally, a whole hierarchy of models should be used for this purpose. The simplest models in this hierarchy contain a minimum of atmospheric processes and their workings may be clearly understood. They can thus provide a basic 'physical intuition' or 'conceptual framework', which can be applied to the interpretation of models of intermediate complexity, involving a larger selection of processes. An understanding of the intermediate models in turn aids the interpretation of the most complex general circulation models. Each type of model may help in the interpretation of observed data. 'Theoretical studies' can often be thought of as examples of the simpler, idealized, kinds of model in this hierarchy.

Controlled, hypothesis-testing, experiments cannot be performed on the large-scale atmosphere itself; they can, however, be carried out on models, for example to explore the relative importance of different processes and to assess the possible impact of perturbations to the climate system. In this sense, models play an important role as proxy atmospheres.

4.2. Simple Theoretical Models

There have been several significant theoretical and conceptual advances during the past decade. Perhaps the most far-reaching has been the general acceptance that, to a first approximation, the climatological, zonal-mean state of the extratropical middle atmosphere can be thought of as arising from a competition between radiative and dynamical processes. Dynamics 'pushes' against a 'radiative spring' that is continually trying to relax the middle atmosphere towards a radiatively-determined state that would be markedly different from that currently observed. This viewpoint, originally proposed in the early 1970s, can be studied with a hierarchy of models involving a fairly full treatment of radiative processes but varying degrees of dynamical sophistication. The most important dynamical processes in the simpler models of this hierarchy are associated with wave motions, and the influence of these waves on the zonal-mean state can conveniently be summarised by the Eliassen-Palm flux divergence. During the MAP period our understanding of this quantity and the associated 'transformed Eulerian-mean' formulation of the zonal-mean equations has continued to improve, and these theoretical ideas have been used as interpretative tools in numerous observational and modelling studies of the middle atmosphere.

Other middle atmosphere phenomena have been modelled using theoretical wave, mean-flow interaction ideas. Examples include the stratospheric sudden warming, for which such a model was originally proposed by Matsuno in 1971. Some extensions to Matsuno's quasi-linear model have been made during the past decade, although it now appears that further major advances will probably require fully nonlinear models and a better appreciation of vortex-interaction dynamics. Some progress has been made in unraveling the causes of the equatorial quasi-biennial oscillation, and especially in extending the model of

HOLTON and LINDZEN (1972) to include meridional structure. However, no model has yet produced a robust set of quantitative, as opposed to qualitative, simulations. Advances have been made in the understanding of the stratopause and mesopause semi-annual oscillations, the former apparently involving accelerations due to Kelvin waves, planetary waves, mean advection and perhaps gravity waves (see 4.4) and the latter probably mainly involving breaking gravity waves.

The mesopause semi-annual oscillation is one of several phenomena in which the vertical transfer of momentum by upward-propagating gravity waves, and the subsequent forcing of the mean flow when they break, are thought to be significant. Indeed, these processes are believed to be crucial for maintaining the upper mesosphere at solstice in a state that is far from radiative balance, with low temperatures in the summer and higher temperatures in the winter. Since the paper of LINDZEN (1981) there have been a number of attempts to derive parameterizations of the drag and diffusion due to the highly complex, nonlinear, gravity-wave breaking process. Parameterizations of this kind have been used, with some degree of success, in global models of the middle atmosphere.

Wave, mean-flow theory has also helped our understanding of transport processes in the middle atmosphere, in so far as they describe the changes to zonal-mean mixing ratios brought about by meridional and vertical flow. There had previously been a tendency for the transport 'due to eddies' and 'due to mean-flow advection' to be regarded as separate, and perhaps competing, processes. In the last decade it has been realized not only that the very definitions of these components of transport depend on the type of averaging employed but also that the two are closely linked: in the absence of eddies, the mean-flow advection will generally be very small. For many purposes a 'Lagrangian-mean' formulation of transport, or some close relative (such as the transformed Eulerian-mean, mentioned above), may be preferable to the more traditional Eulerian-mean approach.

Following the identification of what may be called a 'breaking planetary wave' in satellite observations of the stratosphere (McINTYRE and PALMER, 1983), there have been a number of theoretical attempts to model this strongly nonlinear process. One example of such a flow occurs in the nonlinear theory of barotropic Rossby-wave critical layers, where a judicious combination of analytical and numerical techniques has yielded valuable insights in certain parameter regimes. While these regimes may be quite far from those encountered in the middle atmosphere, some theoretical results probably carry across to more realistic situations. There has also been an upsurge of interest in the use of maps of the potential vorticity on isentropic surfaces as diagnostic tools: these have the advantage of avoiding preconceived notions of the flow being split into 'zonal-mean' and 'wave' parts, although it is still unclear how best to interpret them in a detailed, quantitative way.

4.3 Intermediate Models

In this section we consider models that treat selected aspects of the time dependent dynamics of the middle atmosphere in some detail but do not attempt to include the full range of physical and chemical phenomena believed to be important. Such models have been used for a number of important studies over the last decade.

Examples of intermediate models include the two-dimensional, zonally-symmetric models, with parameterized eddy-fluxes, whose simplified dynamics allow large computer resources to be focused on the transport and detailed photochemistry of numerous chemical species. Several of these models have used the new formulations of zonal-mean transport mentioned in the previous section. Note, however, that current eddy parameterizations are mostly 'non-interactive' in the sense that they cannot respond to changes of the mean state. See e.g., HAIGH and PYLE (1982), GARCIA and SOLOMON (1985) and PLUMB and MAHLMAN (1987) for a selection of cases from the last ten years.

Other intermediate models have been used to look in detail at nonlinear processes that are not accessible to small-amplitude theory. For example, the high-resolution, barotropic model of JUCKES and McINTYRE (1987) is a valuable tool for studying Rossby-wave breaking and nonlinear vortex interactions in what may be regarded as a crude model of a single isentropic layer in the mid stratosphere.

At lower horizontal resolution but with 33 vertical levels, the stratosphere-mesosphere model developed at the U.K. Meteorological Office (with assistance from Oxford University) has been used for idealized studies, such as that of the linear and nonlinear response of the middle atmosphere to large-scale forcing imposed at 100 mb (O'NEILL and POPE, 1988). Although lacking a troposphere, this model can be run in a mode similar to that of the general circulation models described in 4.4, provided that lower-boundary data are specified from observations (e.g. FAIRLIE and O'NEILL, 1987). This allows good simulations of middle atmospheric processes without requiring the additional large computer resources that would be needed to produce good tropospheric simulations as well.

Further intermediate models, designed to study one important aspect of the dynamics of the middle (and upper) atmosphere, are the linear numerical tidal models. These incorporate detailed radiative forcing and damping, and frictional processes (including ion drag and molecular diffusion in the thermosphere), together with allowance for fairly realistic zonal-mean background zonal winds: see e.g., FORBES (1984). Theoretical development of models of this kind has continued throughout the MAP period, and comparisons have been made with rocket and radar tidal observations that are localized in time and space. However, comparisons with continuous, global measurements are still rather limited, owing to the difficulty of isolating tidal information from available satellite data.

4.4. Complex General Circulation Models

General circulation models (GCMs) involve numerical solution of the nonlinear primitive equations from the ground upwards, including as many physical and chemical processes, and employing as high a resolution, as are permitted by available computer resources. Such models tend to be used for two broad classes of controlled experiment: short-term runs for the detailed simulation of specific observed events (e.g. sudden warmings) and longer-terms runs from which 'climatologies' can be constructed for comparison with current observational climatologies. As models become more successful in the latter mode, we shall be able to place more confidence in lengthy runs intended to predict possible changes in climate due, for example, to increasing levels of carbon dioxide or pollutant chemicals such as chlorofluorocarbons.

Most GCMs have been designed primarily for study of the troposphere, and include only a few stratospheric levels; even so, several of these have made important contributions to our knowledge of the lower stratosphere. However, during the last ten years a number of GCMs have been built specifically with middle atmospheric applications in mind; these include those developed at NCAR (BOVILLE and RANDEL, 1986), GFDL (MAHLMAN and UMSCHEID, 1984, 1987), CNRM (CARIOLLE and DEQUE, 1986), CSIRO (HUNT, 1986), NASA Langley Research Center

(GROSE et al., 1987) and Goddard Institute for Space Studies (RIND et al., 1988).

The GFDL "SKYHI" model, for example, has 40 levels, from the ground up to about 80km, with a vertical resolution of about 2½ km in the middle atmosphere and a horizontal resolution that has been increased from 9° latitude by 10° longitude in early runs through to 1° by 1.2° in the latest experiments. It includes a fairly complete set of physical parameterizations in the troposphere, has a state-of-the-art treatment of radiation, but only a simple treatment of ozone photochemistry. A nonlinear horizontal diffusion and a Richardson-number dependent vertical diffusion are included in the momentum equations. No parameterization of the drag and diffusion due to breaking gravity waves is used, although the finest-scale version of the model does explicitly represent some of these wave motions.

A 5° latitude by 6° longitude version produces zonal jets that are much too strong in the mesosphere compared with observations. These are consistent with the fact that the winter stratosphere is too cold (a common problem with middle atmosphere GCMs) and the latitudinal temperature gradient in the mesosphere is not reversed, as it is in the observations. It appears that at this resolution the planetary waves are too weak in the troposphere, and are rapidly damped in the lower stratosphere, leaving too little wave activity to drive the middle atmosphere very far from the radiative state (see 4.2). In a higher resolution (1° by 1.2°) version of the model the tropospheric planetary waves are stronger, propagate to greater heights in the stratosphere and mesosphere, and produce greater zonal-mean forcing there; moreover, previously unresolved gravity waves also provide significant mean-flow driving. As a result, rather more realistic zonal jets are produced.

The 5°x6° model simulates quite well the three observed types of Kelvin wave in the equatorial middle atmosphere. It produces a realistic-looking semiannual oscillation in equatorial latitudes but not a quasi-biennial oscillation; the latter deficiency may be due to insufficient vertical resolution. Phenomena resembling minor and major stratospheric sudden warmings have arisen spontaneously during integrations of the model. A more recent study by HAMILTON and MAHLMAN (1988) finds the interesting result that, in the 3°x3.6° version of the SKIHI model, the westerly accelerations of the semiannual oscillation are driven mainly by gravity waves, rather than by the Kelvin waves that are usually held to be responsible. More work will be need to be done to determine whether the same is true of the real middle atmosphere.

Other middle atmosphere GCMs include physical and chemical processes not present in the SKYHI model, although at the expense of reduced resolution. For example the 28-level CNRM model incorporates parameterized ozone photochemistry that interacts with the dynamics, while the 12-level NASA Langley model includes fairly comprehensive 'offline' chemistry, partitioned into families such as O_x, NO_y and Cl_x. Both of these have rather low horizontal resolution.

4.5. Conclusions

With the possible exception of the tidal modelling, none of the developments described above were planned directly as Middle Atmosphere Program enterprises. However, there is no doubt that MAP activities have provided valuable assistance in a number of these areas (especially those relating to observations of gravity waves) and have generally stimulated research into the modelling of the middle atmosphere. The MAP handbooks have brought together an important body of information on measurement facilities, provided summaries of current knowledge of the middle atmosphere in the form of MAP Study Group Reports, and furnished useful compilations of observations, such as the Draft

Reference Middle Atmosphere in Volume 16. The latter has already been used extensively for judging the performance of models.

Comprehensive modelling of the middle atmosphere is still a comparatively young discipline. There will be a long way to go before a detailed understanding of the interplay of dynamics, radiation, photochemistry and transport there is achieved, so that full descriptions of phenomena like the 'antarctic ozone hole' can be given and credible predictions of long-term climate change in the troposphere-stratosphere-mesosphere region can be made. Progress will call for the incorporation into GCMs of new physical and chemical processes, and the use of higher resolution, as computer power grows. However, the understanding and assessment of these increasingly complex models will still require a range of simpler models.

Perhaps most important in the future, however, will be the need for a closer interaction between observation and modelling. At present, the choice of middle atmosphere data to be gathered is determined mainly by instrumental capabilities and the ingenuity of experimentalists. Modellers respond to this by attempting to simulate and interpret the available data. Resources allocated for data-gathering often far outweigh those for data-interpretation, so that considerable quantities of data are never studied at all (see the report of the U.S. Panel on MAP, MAP Handbook, Vol. 11, pp. 113-120). One way of avoiding this mismatch may be to encourage modellers to play a more active part in suggesting what observations should be made and in laying down resolution requirements for observing systems. Another important role for models may be to use them for 'data assimilation', to help make up for the deficiencies and incomplete coverage of observations.

This brief review has not attempted to provide a fully comprehensive account of the progress in Theory and Models during the MAP period; moreover, it inevitably reflects the author's biases. More detailed summaries of current understanding can be found for example in Chapters 6 and 12 of WMO (1986) and in the book by ANDREWS, HOLTON and LEOVY (1987).

4.6 Recommendations

(1) Further enhancements to general circulation models will be required, including:
(a) improved vertical and horizontal resolution,
(b) Online treatment of detailed photochemistry of more chemical species,
(c) improved parameterization of sub-grid-scale processes, such as the effects of breaking gravity waves.

(2) Improved, dynamically-based diagnostics will be required for better interpretation of models and atmospheric observations and for more discriminating comparisons between the two. These will need to avoid reliance on simple 'zonal-mean, eddy' separations of the data and the use of quasi-linear theory.

(3) Further simple models will be needed to strengthen the hierarchy of models of differing complexity.

(4) Points 1(c), 2 and 3 will call for further theoretical studies of a fundamental dynamical nature.

(5) Enhanced interaction between theoreticians and observationalists will be needed.

CHAPTER 5

RECENT ADVANCES IN THE CHEMISTRY OF THE MIDDLE ATMOSPHERE

5.1 Introduction

Since the MAP Planning document was written, observations have shown that ozone is declining over the entire Earth, with a particularly rapid rate over the Antarctic continent. A recent re-analysis of satellite data has led to the conclusion that the ozone column averaged from 53°N to 53°S has decreased by about 2.5 percent between October 1979 and October 1986. Concentrations near 40 km altitude appear to have decreased by 3 to 9 percent over the same period of time. A fraction of these observed changes is attributed to the coincident decrease in solar activity during this period. However, increasing emissions in the atmosphere of industrially produced chlorofluorocarbons have also contributed substantially to the reduction of the ozone density. An analysis of the column ozone measurements from ground-based Dobson instruments over a longer period of time (1969-1986), after allowing for the effects of solar variability and other natural variations (such as the quasi-biennial oscillation of the tropical zonal wind) shows a decrease in total ozone ranging from 1.7 to 3.4 percent between 30 and 64 degrees N, with the most pronounced reductions during the winter months. Model calculations simulating the response of the atmosphere to increasing concentrations of trace gases (such as carbon dioxide, methane, nitrous oxides and the chlorofluorocarbons) are broadly consistent with the observed ozone trend except at winter mid-and high latitudes where the models clearly underestimate the ozone destruction rate associated with global human perturbations.

Ground-based and satellite observations have also revealed that a dramatic ozone decline takes place over Antarctica each spring (September and October) since the late 70's. The October monthly mean ozone column was about 35-40 percent lower in October 1986 than in October 1979. When the ozone hole was discovered in 1985, no model based on the current knowledge of the gas phase chemistry was able to reproduce this large ozone decrease, suggesting that unknown chemical or dynamical processes were taking place in the lower stratosphere after the return of the Sun at the end of the polar winter.

Recent research (field measurements and laboratory work) has demonstrated chemical mechanisms involving man-made chlorine are the primary cause for the observed ozone decline over Antarctica. Active chlorine (Cl, ClO) is released from chlorine reservoirs (HCl, $ClONO_2$) in the presence of polar stratospheric clouds or polar stratospheric haze, which are formed in the lower stratosphere when the temperature decreases below a certain threshold (185-195 K). The heterogeneous processes involved in the liberation of active chlorine on the surface of ice particles in the clouds have only recently been studied in the laboratory and more quantitative studies are clearly needed. The important of the heterogeneous reactions outside the Antarctic regions is still poorly understood and, for example, the possible role of sulphuric acid aerosols in the Junge layer (especially after large volcanic eruptions) need to be assessed. There is a growing concern that ozone depletions may extend to latitudes outside of Antarctica and might become substantial, for example, over the Arctic regions.

The purpose of this brief contribution is to review recent studies of chemical processes in the middle atmosphere with a particular emphasis on problems related to the ozone hole.

5.2 The Role of Hydrogen, Nitrogen and Halogen Compounds in the Ozone Budget

Ozone in the stratosphere is produced from the photodissociation of molecular oxygen

$$O_2 + h\nu \rightarrow O + O$$

followed by the third-body recombination

$$O + O_2 + M \rightarrow O_3 + M$$

where M is a particle that interacts to allow momentum conservation. Ozone is photodissociated by ultraviolet and visible light

$$O_3 + h\nu \rightarrow O_2 + O$$

and the oxygen atom is often reconverted into ozone. However, a small proportion of these oxygen atoms reacts with ozone through a direct recombination reaction.

$$O + O_3 \rightarrow 2O_2$$

Because of the strong temperature dependence of the rate of this reaction, this destruction mechanism of odd oxygen introduces a negative feedback ozone and temperature, particularly in the upper stratosphere, where this reaction plays a non-negligible role. Other destruction mechanisms of ozone may limit the magnitude of this effect, such as the following cycles which catalyses the recombination of odd oxygen species in the mesosphere, in the presence of hydrogen radicals. Indeed, above 55 km or so, the most efficient destruction mechanisms of O and O_3 are due to

$$\begin{array}{lrcl} & H + O_3 & \rightarrow & OH + O_2 \\ & OH + O & \rightarrow & H + O_2 \\ \hline \text{Net:} & O + O_3 & \rightarrow & 2O_2 \end{array}$$

and

$$\begin{array}{lrcl} & OH + O & \rightarrow & H + O_2 \\ & H + O_2 + M & \rightarrow & HO_2 + M \\ & HO_2 + O & \rightarrow & OH + O_2 \\ \hline \text{Net:} & O + O & \rightarrow & O_2 \end{array}$$

Hydroxyl radicals and hydrogen atoms are produced by dissociation or oxidation of water vapour, methane and molecular hydrogen. These gases are originating at the Earth's surface and transported into the middle atmosphere.

In the stratosphere, the destruction of odd oxygen is catalysed by the presence of nitrogen oxides:

$$\begin{array}{lrcl} & NO + O_3 & \rightarrow & NO_2 + O_2 \\ & NO_2 + O & \rightarrow & NO + O_2 \\ \hline \text{Net:} & O_3 + O & \rightarrow & 2O_2 \end{array}$$

Nitric oxide is produced in situ in the stratosphere by oxidation of nitrous oxide, a gas produced at the surface and transported into the stratosphere.

Another catalytic destruction of ozone

$$\begin{array}{llll} & Cl + O_3 & \rightarrow & ClO + O_2 \\ & ClO + O & \rightarrow & Cl + O_2 \\ \hline \text{Net:} & O_3 + O & \rightarrow & 2O_2 \end{array}$$

results from the presence of chlorine produced essentially by UV photodecomposition of industrially produced chlorofluorocarbons. In the lower stratosphere and in the troposphere, the most efficient ozone destruction mechanism is due to a cycle involving the presence of hydrogen radicals.

$$\begin{array}{ll} & OH + O_3 \rightarrow HO_2 + O_2 \\ & HO_2 + O_3 \rightarrow OH + 2O_2 \\ \hline \text{Net:} & 2O_3 \rightarrow 3O_2 \end{array}$$

Other cycles may play a significant role and even become dominant under specific conditions, such as in the cold stratosphere over Antarctica (see below).

For all these cycles to occur, the presence of solar radiation is required. The production and destruction rates of ozone depend therefore on the magnitude of the solar irradiance, and its penetration in the atmosphere. Furthermore, the heating of the middle atmosphere, and consequently its temperature, depends on the ozone density, which in turn is a function of the local temperature. These various non-linear coupling mechanisms introduce complex feedbacks which are generally negative and tend to stabilize the atmosphere. Some of these feedbacks, however, could eventually be positive and amplify the effects of perturbations caused by human activities. It should be noted that most models based on our current knowledge of photolytic ozone production mechanism and of ozone catalytic destruction tend to underestimate the ozone density in the upper stratosphere and mesosphere. This problem requires further attention.

5.3 Antarctic Ozone

5.3.1 Observations

In 1985, scientists of the British Antarctic Survey reported that the ozone column measured in October over the scientific station of Halley Bay (76°S, 27°W) had gradually decreased by about 40 percent between 1979 and 1984 (FARMAN et al., 1985). These results were based on ground-based observations obtained by means of a Dobson spectrometer. The British scientists suggested that this trend could have been produced by chlorine compounds of anthropogenic origin. Subsequently, satellite data available since 1979 were re-analysed. They showed that the ozone hole is formed early in September and lasts until November, and that it extends over essentially the entire Antarctic continent. They also confirmed the Dobson measurements as well as other ground-based data obtained for example from both the Japanese scientific station located at Syowa (69°S, 40°E) and the American station at the South Pole. Finally, the satellite measurements showed that the decrease in ozone is not entirely confined in the polar vortex but extends to latitudes near 45°S although with smaller amplitudes. The most recent data analysis suggests that since 1979, Antarctic ozone has noticeably been perturbed all year round.

A first campaign was organised by the United States to perform coordinated measurements at the U.S. station of McMurdo in spring 1986 and a second took place in August and September, 1987 during which, in addition to the McMurdo observations, measurements were taken from two airplanes flying from Punta Arenas (Chile) into the polar vortex at 12 and 18 km altitude respectively (See for example, papers in the special issues of Geophysical Research Letters, 15(8), August 1988 and of the Journal of Geophysical Research, 94(D9), August, and 94(D14) November, 1989).

The first campaign confirmed the recurrence of the "ozone hole". Ozone profile measurements made from McMurdo in 1986 showed that the altitude of the ozone depletion ranged between 12 to 22 km. Unusual chlorine and nitrogen concentrations were revealed by comparison with mid-latitude conditions. For example, observations showed very low abundances in NO_2 and large amount of ClO in the lower stratosphere, near 20 km. For the first time OClO molecules were detected, confirming the importance of chlorine chemistry in the polar vortex.

The second campaign confirmed the previous findings. The ClO abundances at the highest latitude, around 18.5 km were found to be 100-500 times greater than those observed at mid-latitudes, with maximum values between 0.5 and 1 ppbv at 18.5 km and a steep decrease towards lower altitudes. The stratospheric vortex was also found to be highly denitrified as well as dehydrated. The abundance of BrO of a few pptv was observed around 18 km altitude and was decreasing at lower levels. Very low values of CFC-11 and 12, were also measured.

An important feature is the apparently more frequent occurrence of stratospheric clouds in both winter polar regions observed by SAM II experiment on board Nimbus 7 satellite since late·1978. The presence of these clouds is noticeable in June-September 1979 with similar signatures repeated each year. The same data set shows a noticeable minimum in October every year. Additional measurements are needed to understand the processes involved in the formation and disappearance of these clouds. Their importance is justified by their potential role in releasing gaseous active chlorine from chlorine reservoirs.

5.3.2 Theories

Different theories have been suggested to explain the increasingly stronger springtime ozone minimum over Antarctica. Some of these theories invoke natural fluctuations while others suggest a perturbation effect linked to industrial activity.

Among the first type of explanations, a theory suggests that the strength of planetary wave activity could have been reduced over the last decade eventually as a result of changes in the sea water temperature. This effect would bring the southern hemisphere closer to radiative equilibrium conditions with reduced poleward and downward transport of ozone and heat, the formation of upwelling after the return of the Sun at high latitude in spring and the later appearance of the final polar warming. The ozone depletion in the lower stratosphere would then be produced by intrusion of tropospheric air which is known to be poor in ozone. This mechanism, if real, should also introduce relatively high levels of gases such as CH_4 or the CFCs which are produced at the Earth's surface and are therefore most abundant in the troposphere. The recent measurements made over Antarctica clearly show that the density of these gases in the polar vortex is particularly low. This observation suggests that no upwelling takes place over the polar region, in winter and early spring. Thus, dynamics cannot explain by itself the formation of an ozone hole but meteorology nevertheless plays an important role by setting up the special conditions required for some chemical processes to happen (see 2.5.2). Meteorology is also controlling the termination phase of the ozone decrease in late spring. It is also interesting to note that the August and September temperatures show little change over the 1979-1986 period, suggesting little dynamical variation during the last decade. The cooling observed since 1979 in the lower stratosphere in October and November (after the occurrence of the ozone depletion) should be attributed, at least in part, to a reduction in the absorption of solar radiation by ozone and in the related diabatic heating.

Another theory invoked the effect of solar activity. Nitrogen oxides, which efficiently destroy ozone in the stratosphere when solar radiation is present, are produced in the thermosphere (above 85 km) by ionospheric processes. The production of NO_x at these levels, which is controlled by the intensity of extreme ultraviolet radiation, is highly dependent on the solar activity. Large amounts of nitrogen oxides were produced during the solar maximum period in the late 70's and early 80's. If NO_x is transported downwards in the winter polar region by the general circulation, and if it reaches the lower stratosphere in fairly large amounts by the end of the winter, it could efficiently destroy ozone as the Sun returns over Antarctica. Observations of different nitrogen compounds indicate however that the lower stratosphere is highly denitrified, so that this theory has to be rejected.

Other theories suggest that the formation of the ozone hole is related to the release in the atmosphere of increasing amounts of chlorofluorocarbons. The line between the rapid destruction of ozone below 20 km and the emissions of the CFCs is not straightforward since at these heights, active chlorine is, in principle, rapidly transformed into chlorine reservoirs such as HCl and $ClONO_2$, without effect on ozone. If, under the special conditions prevailing in the lower stratosphere over Antarctica, these reservoirs could be destroyed by some mechanisms to be identified (and discussed below), ozone could be removed in about 15–20 days by several catalytic cycles, provided that the level of ClO would reach 0.5 to 1 ppbw. Possible cycles are

$$
\begin{array}{lllll}
Cl & + O_3 & \rightarrow ClO & + O_2 \\
OH & + O_3 & \rightarrow HO_2 & + O_2 \\
HO_2 & + ClO & \rightarrow HOCl & + O_2 \\
HOCl & + h\nu & \rightarrow OH & + Cl \\
\hline
\text{Net:} \quad O_3 & + h\nu & \rightarrow 3O_2 &
\end{array}
$$

$$
\begin{array}{llll}
Cl + & O_3 & \rightarrow ClO + O_2 \\
Br + & O_3 & \rightarrow BrO + O_2 \\
ClO + & BrO & \rightarrow Cl + Br + O_2 \\
\hline
\text{Net:} & 2O_3 & \rightarrow 3O_3
\end{array}
$$

$$
\begin{array}{lll}
2(Cl + O3 & \rightarrow & ClO + O2) \\
ClO + ClO + M & \rightarrow & Cl_2O_2 + M \\
Cl_2O_2 + h\nu & \rightarrow & ClOO + Cl \\
ClOO + M & \rightarrow & Cl + O_2 + M \\
\hline
\text{Net:} \quad 2O_3 + h\nu & \rightarrow & 3O_2
\end{array}
$$

$$
\begin{array}{lll}
2(Cl + O3 & \rightarrow & ClO + O2) \\
ClO + ClO + M & \rightarrow & Cl_2O_2 + M \\
Cl_2O_2 + M & \rightarrow & Cl_2 + O_2 + M \\
Cl_2 + h\nu & \rightarrow & 2Cl \\
\hline
\text{Net:} \quad 2O_3 + h\nu & \rightarrow & 3O_2
\end{array}
$$

The second of these cycles, to be efficient over Antarctica, requires BrO to be present in the polar vortex. Observations made in September, 1987 in the region of the ozone hole, indicate that the amount of BrO is not larger in the vortex than outside the vortex (5–15ppbv). However, observations of OClO over the station of McMurdo, Antarctica, in September, 1986 and 1987, with levels 50 times larger than expected under mid-latitude conditions, suggest that Bromine monoxide could play a role. Indeed, if our understanding of the chlorine chemistry is correct OClO is produced by the following reaction

$$ClO + BrO \rightarrow OClO + Br$$

and accumulates during nighttime. During daytime, OClO is photodissociated in the visible and its concentration decreases. The photochemistry of OClO is entirely different from that of ClOO. This form of chlorine oxide is believed to be produced by photodissociation of the Cl_2O_2 dimer. Anyhow, the observation of elevated levels of OClO over Antarctica provides an important indication that the amount of ClO is extremely high in the polar vortex at the end of the winter and that the inactive chlorine reservoirs are probably destroyed in late August and early September. Indeed, observations made in late September, 1987 from the NASA ER-2 aircraft indicate that the mixing ratio of chlorine monoxide at 18.5 km altitude is a factor of 100 larger within the region of very low ozone than at mid-latitudes. The measured density of ClO at 18.5 km (about 1ppbv) is sufficiently large to explain the destruction of ozone at this height, if our current understanding of the chlorine dimer catalytical cycle is correct, the abundance of ClO seems to decrease rapidly below 18 km, so that other processes (including a vertical downward transport) might contribute to the the ozone destruction below about 15 km.

As indicated earlier, the chlorine theory requires significant amounts of active chlorine to be liberated from the reservoirs (HCl and $ClONO_2$). It also requires low levels of NO_x to avoid the transformation of ClO into $ClONO_2$. Several ways to destroy the chlorine reservoirs have been suggested. These explanations are constrained by the fact that the proposed mechanism should operate only in early spring, primarily in the lower stratosphere over Antarctica as opposed to other altitudes, latitudes and time of the year, i.e., in a stable region with temperatures lower than about 200 K. It was shown that the condensation of nitric acid (FNO_3) could condense into small particles as soon as the temperature of the lower stratosphere decreases below about 205K. Ice crystals can start forming only below 191 K. A polar stratospheric haze with small $HNO_3.H_2O$ and $HNO_3.3H_2O$ particles should thus be formed in the lower stratosphere at temperatures between 205 and 191 K. Below this latter temperature H_2O and HCl would also freeze, together with HNO_3. The largest particles, which form the so-called polar stratospheric clouds (PSCs) are expected to be removed from the stratosphere by gravitational sedimentation. This mechanism may contribute to remove NO_x and H_2O from the lower stratosphere (if S_2O_5 and $ClONO_2$ are converted into HN_{O3} by heterogeneous reactions on the surface of the ice particles). As nitric acid is removed from the gas phase, the abundance of the OH radicals, which are destroyed essentially by HNO_3 in the lower stratosphere, is expected to be significantly enhanced. OH is very efficient in destroying HCl and producing active chlorine. When HNO_3 is again released into the gas phase by evaporation at higher temperature, active chlorine is transformed back into HCl and $ClONO_2$ and the ozone decay slows down. A detailed quantitative study of this mechanism is required to establish if it can entirely explain the observed springtime polar ozone trend and if it would account for the rather sudden appearance of the ozone hole after 1979.

The first studies of ozone depletion over Antarctica pointed out that the formation of the ozone hole in spring could be associated with the presence of polar stratospheric clouds which are produced and observed in winter. The following reactions occurring heterogeneously on the surfaces of ice particles were suggested as being important processes:

$$HCl + ClONO_2 \rightarrow HNO_3 + Cl_2$$
$$H_2O + ClONO_2 \rightarrow HNO_3 + HOCl$$

The efficiency of these reactions however are expected to be small since the probability for two gas phase molecules to collide on an aerosol surface is low. Laboratory measurements have shown that the destruction of atmospheric gaseous $ClONO_2$ on ice particles is considerably enhanced if HCl is dissolved in these ice particles. In fact, at low temperature, HCl molecules dissolve in ice crystals and the probability for a reaction of gas phase $ClONO_2$ with dissolved HCl to occur at the surface of the solid particles is of the order of 5 to 10 percent at about 200 K for an HIC mole fraction between 3.5×10^{-3} and 1×10^{-2}. Nitric acid, which is produced by this reaction, remains in the condensed phase (so that this process contributes to the denitrification of the stratosphere), while Cl_2 is released in the gas phase on a time scale of a few milliseconds. When the Sun returns over Antarctica in later winter, the chlorine molecule is then photodissociated into two atoms which react immediately with ozone molecules. The reaction of $ClONO_2$ with ice (H_2O) has a collision efficiency of about two percent at 200 K and produced HOCl in the gas phase on a time scale of minutes. Solid solutions of HCl in H_2O ice with a mole fraction of (2.0 - 3.5) 10^{-2} will form in the stratosphere between 193 and 190 K and condensation of small quantities of water vapour leads to nearly complete removal of HCl (and HNO_3) from the gas phase. The following cycle will transform HCl into $ClONO_2$ and NO_2 (in the gas phase) into NHO_3 (in the condensed phase).

$$
\begin{array}{lcl}
ClONO_2(gas) + HCl(solid) & \rightarrow & Cl_2(gas) + HNO_3(solid) \\
Cl_2 + h\nu & \rightarrow & 2Cl \\
2(Cl + O_3 & \rightarrow & ClO + O_2) \\
2(Cl + NO_2 & \rightarrow & ClONO_2) \\
\hline
\text{Net: } HCl(solid) + 2NO_2(gas) + 2O_3 + h\nu & \rightarrow & ClONO_2(gas) + HNO_3(solid)
\end{array}
$$

So far, this mechanism has little effect on ozone. However, if the initial HCl number density (before onset of condensation) is equal or larger than half of the NO_x density (NO_x being the sum of nitrogen oxides readily converted to NO_2), the last reaction in this cycle will no longer be possible due to exhaustion of NO_x. At this stage, ClO accumulates and ozone and is being efficiently destroyed. Thus, during polar night, when stratospheric clouds are present, pre-existing HCl condenses into ice particles and Cl_2 is produced by reactions with $ClONO_2$. As the Sun returns over Antarctica, Cl_2 is photolyzed and NO_x is depleted, producing first $ClONO_2$ molecules and later ClO radicals. It is interesting to note that the initial density of HCl is a key factor in this scheme and that the sudden onset of the Antarctic ozone depletion in the late 1970's could reflect the growth of the HCl density beyond a threshold equal to half the NO_x abundance.

In conclusion, the formation of an ozone hole in spring over Antarctica appears to be due to the action of man-made chlorine in the presence of polar stratospheric clouds. These are observed in the altitude range where a large fraction (eventually more than 90 percent) of ozone is depleted in September. The details of the clouds formation are not yet fully understood and an extensive program in the area of heterogeneous chemistry is <u>urgently needed</u>. Dynamics creates the conditions for the winter temperature to become sufficiently low for these clouds to be produced. The polar vortex is probably nearly isolated from the rest of the stratosphere. The possible intrusion of air from extra polar regions on small scales should however be investigated. Although the ozone hole seems to be particular to conditions prevailing near the South Pole, it is important to determine if the processes involved could play a role in other regions of the world and if large ozone reductions could be produced at present or in the future, for example, in the Arctic region. It is also necessary to determine if the region of large ozone reduction could become wider or deeper and to what extent the air with low ozone could be diluted towards lower latitudes and affect the entire southern hemisphere. If the theory indicating that the ozone hole is linked to increasing abundances of chlorine is proved to be correct, it can be stated that the springtime hole over Antarctica should remain persistent for several decades, even if the release in the atmosphere of chlorofluorocarbons was dramatically reduced. This is a direct consequence of the long atmospheric lifetime (about 100 years) of CFCs. On the other hand, the ozone column abundance in the hole is not expected to further decrease in a substantial way because, in the region where depletion mechanisms are important, almost all of the ozone is already destroyed each spring. It is nevertheless crucial to determine if the extent in altitude and latitude of the PSCs remains unchanged from year to year.

5.4 Conclusions

Although much progress has occurred in the last 10-15 years in understanding the chemical and photochemical processes which control the formation and the destruction of atmospheric constituents, comparisons of models with available observations show, in certain cases, significant disagreements. For example most present models still underestimate the ozone density in the upper stratosphere and mesosphere, suggesting the possible omission of an ozone source or the overestimation of the calculated ozone loss. In cold regions, where solid or liquid particles are present, heterogeneous processes may become important and affect the density of gaseous species such as ozone. Processes releasing active chlorine from HCl and $ClONO_2$ reservoirs are producing elevated concentrations of ClO, leading to the rapid destruction of ozone over Antarctica and possibly over the Arctic region. The importance of these types of processes at other latitudes needs to be assessed. Recently, HOFMANN and SOLOMON (1989) have pointed out that heterogeneous reactions on volcanic aerosols may have been at least partly responsible for the anomalous ozone reduction observed at mid-latitudes following the El Chicon eruption.

5.5 Recommendations

(1) Further investigations of heterogeneous chemistry are urgently needed. Accurate modelling is called for of the competing chemical and microphysical processes which lead to dehydration, dentrification and chlorine activation and removal in the polar winter vortex. Specifically, more knowledge is needed of the nucleation process of H_2O onto HNO_3 aerosols; the solubilities of HCl and HNO_3 in nitric acid and water ices under polar stratospheric conditions; the reactivities of $ClONO_2$, N_2O_5, ClO on sulfuric acid aerosols, both liquid and solid; the condensation and physical chemistry of ternary aerosol systems, including $H_2O/H_2SO_4/HNO_3$ and $H_2O/HNO_3/HCl$.

(2) As well as continued monitoring and study of the conditions which lead to the formation of the Antarctic ozone hole, it is important to determine whether the processes involved could lead to similar depletions in other regions. Favourable pre-conditions already seem to exist for ozone depletion in the Arctic spring, but require further investigation. Further assessment is also needed for the potential for ozone depletion at mid- to high-latitudes following an injection of volcanic sulfuric acid aerosols into the stratosphere.

CHAPTER 6

MIDDLE ATMOSPHERIC ELECTRODYNAMICS

6.1 Introduction and Background

Middle atmospheric electrodynamics (MAE) concentrates on the electrical structure of the stratosphere and mesosphere and on how these regions interact electrodynamically with the remainder of the Earth's environment, i.e. with the troposphere from below and with the ionosphere and magnetosphere from above. It is also sensitive to a variety of ionizing radiations of both electromagnetic and corpuscular structure, which are primarily of cosmic, solar or solar induced origin. The MAP era has heralded in important advances in this field, partly led by the apparent earlier discovery that very large volt/meter (V/m) electrical fields may occasionally occur within the lower mesosphere and upper stratosphere and also be produced locally, thereby giving this region an active role in affecting characteristics of the global electrical circuit.

MAE, of course, encompasses a broad range of topics either related to or in addition to the question of existence for large mesospheric electric fields. These include studies of the bulk ion properties such as ion mobility, density and conductivity (MITCHELL, 1986), of neutral air turbulence through measurement of ion and electron gradients (THRANE et al., 1987; SMITH and ROYRVIK, 1985; BLOOD et al., 1988), of global current systems (HOLZWORTH and VOLLAND, 1986; NORVILLE and HOLZWORTH, 1987), of ion chemistry (c.f. REID, 1986), and of lightning induced electron precipitation in the magnetosphere (RYCROFT, 1973; INAN et al., 1984, 1985; VOSS et al., 1984; and GOLDBERG et al., 1986, 1987). Early measurements of stratospheric electric fields under fairer weather conditions aboard balloons provided evidence that the horizontal field components map primarily from the magnetosphere (MOZER, 1971) and vertical field components from the troposphere (TANAKA et al. 1977). During MAP, perturbations on this system by thunderstorms (HOLZWORTH, 1981), large "non-electrical" storm systems (BARCUS et. al., 1986) and by solar induced disturbances such as solar proton events (HOLZWORTH and MOZER, 1979) have also been reported. More recently, HOLZWORTH (1989) has reported that stratospheric horizontal electric fields track neutral wind wave rotational structure, rearranging our thoughts on the origin of horizontal fields in the stratosphere. This latter result was made possible through the newly developed technology of superpressure balloons. It is now clear that the neutral and plasma components of the atmosphere strongly interact within the middle atmosphere, as shown by the relationship between plasma structure and neutral winds, waves and turbulence.

Prior to the MAP period, the middle atmosphere was considered to be passive and uninteresting in an electrodynamic sense, simply providing a conduit for signals and currents travelling upward and/or downward within the near earth environment. This is evidenced for example, by the omission of MAE as a field of research within the MAP Planning Document (1976). After the onset of MAP, these impressions rapidly changed, initiated by a NASA sponsored MAE Workshop in Reston, Virginia in January, 1979 (MAYNARD, 1979). Following the workshop, MAP formed an MAE study group, IAGA organized Working Group IIA on MAE, and the Committee of Atmospheric and Space Electricity (CASE) of the AGU incorporated MAE as an important field of interest. In the last decade, there have been numerous sessions dedicated to MAE at various national and international meetings, and several review papers have appeared outlining progress in the field. Some of these include MAYNARD (1980), HOLZWORTH (1981), KELLEY (1983), HALE (1984), MAYNARD et al. (1984), and GOLDBERG (1984, 1990). The MAP Handbook 19, Rocket Techniques, also includes several chapters dedicated to measurement techniques relating to MAE. Finally, a continuing program of rocket and balloon campaigns has been conducted on a worldwide basis throughout the entire MAP Period, leading to many of the results which will be discussed in this brief review.

6.2 Large Middle Atmospheric Electric Fields

One reason that the middle atmosphere was (and still is by many) considered to be passive in an electrodynamic sense, and thereby incapable of supporting electric fields above a few mV/m, can be attributed to its large (relatively infinite) electrical conductivity. Figure 6.1 (HALE, 1984), illustrates the wide range of values for electrical conductivity in the middle atmosphere under a variety of geophysical conditions, albeit recognizing that even the lowest values in the figure are considered high for the purpose of supporting electric fields above the mV/m size. It was therefore somewhat of a surprise when BRAGIN et al. (1974) and TYUTIN (1976) reported the discovery of large (V/m) vertical electric fields within the lower mesosphere using rocket-borne field mills on four separate rocket flights. They concluded that this was a permanent feature of the region, always contained in an altitude domain having a characteristic half width of 10 km. In 1981, Hale et al. reported vertical electric field measurements by nine separate rocket flights launched from various sites at high-, mid- and low-latitudes, each making use of an asymmetric double probe activated during the parachute-borne descent of the payload. They detected apparently large V/m fields on only two of the nine flights, implying that the occurrence of the V/m fields were relatively infrequent, and certainly not a permanent feature of the middle atmosphere.

Meanwhile, MAYNARD (1986) developed a sophisticated rocket-borne technique to measure the vector electric field in the middle atmosphere. This consisted of a self contained system of three orthogonal and symmetrical pairs of booms mounted on a sphere of much smaller diameter than the boom lengths, which contained a telemetry transmitter and a gyroscope for attitude determination. The entire package was deployed from the main payload during upleg, and then acquired most of its data during the downleg portion of a free-fall trajectory, completely isolated from the main payload and rocket motors. The first measurement using this technique occurred on July 31, 1980, at Wallops Island, Virginia and once again indicated the presence of a large vertical electric field with the characteristic 10 km half width (MAYNARD et al., 1981). Simultaneous conductivity measurements showed a depletion within the region of enhanced electric field, but of 1-2 orders of magnitude less than the electric field increase, in apparent violation of Ohm's law, causing speculation that the fields might be locally generated, e.g. through an emf source.

Large horizontal electric fields were observed for the first time in October, 1980, at Andoya, Norway (MAYNARD et al., 1984) and compared with the horizontal wind directions, the latter obtained independently with nearly simultaneous meteorological rockets. The electric field directions were found to anticorrelate with the wind directions within the height region where the fields reach V/m magnitudes, which provided the first direct evidence for a possible neutral wind driver as a source for the V/m fields. Furthermore, although auroral precipitation events were in progress during both measurements, the fields were observed to occur below those heights where significant ionizing radiation had penetrated, which contributed to the suggestion that electrical conductivities above 10^{-10}S/m would probably be unable to support such fields.

The interpretation of data presented here as large electric fields has been and still is subject to controversies which must be resolved before the reality of the V/m electric fields is widely accepted. The early field mill measurements

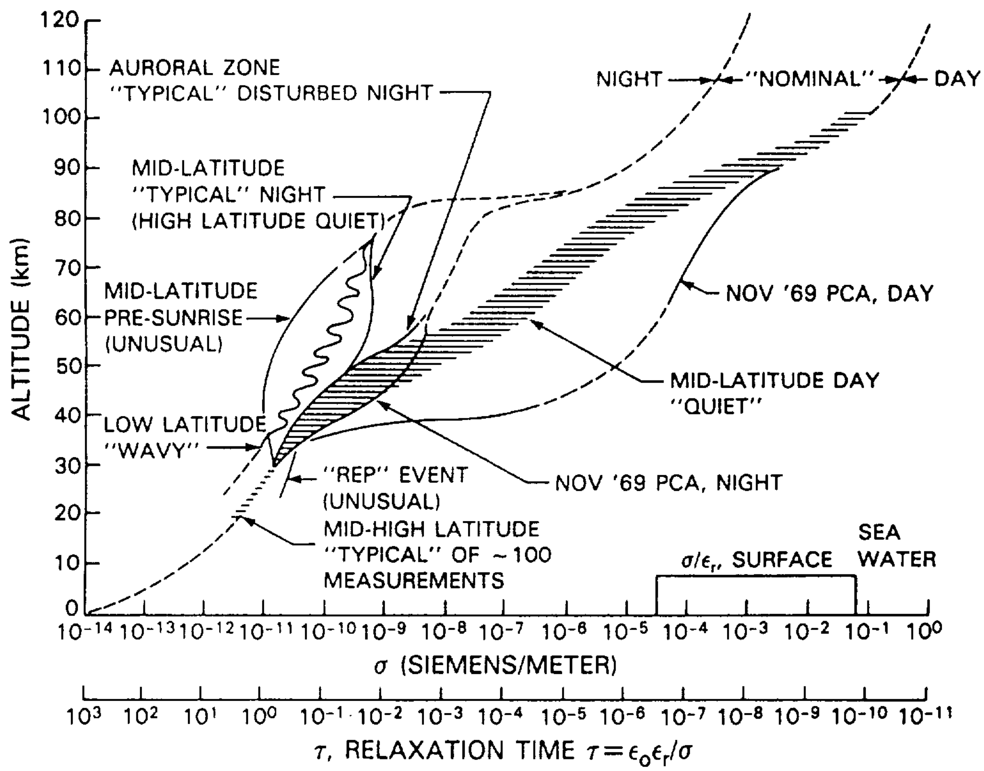


Figure 6.1. Total atmospheric electrical conductivity and relaxation time under a wide range of geophysical conditions (after Hale, 1984).

were criticized because of known difficulties in using this technique aboard rockets. More recently, KELLEY et al. (1983) measured large electric fields near 66 km using a payload geometry with two sets of booms orthogonal to the payload axis, each pair of different length. However, the field measured by the shorter boom probes was found to be of higher magnitude than that measured by the probes on the longer booms, causing them to conclude that the measured field was probably caused by a charged wake. They also inferred from this result that all previously reported measurements should be subject to closer scrutiny to establish their validity.

In support of his earlier measurements, HALE (1984) showed two independent pairs of measurements made a day apart at Poker Flat, Alaska in January 1982. Hale measured vertical electric fields on each payload with both an asymmetric double probe and a symmetric boom-mounted probe technique, and was able to discern apparent large electric fields between 60 and 70 km altitude with each technique producing nearly identical values for profile shape and magnitude on the same flight. This demonstrated consistency between these two independent techniques, at least as applied to the Hale payloads. Later, MAYNARD (1986) showed that his instrument could measure apparently anomalous electric fields prior to its separation from the main rocket payload, but that once separated and in a normal operating mode, measurement values returned to anticipated levels.

More recently, CURTIS (1987) produced a theory which is consistent with the measurements of MAYNARD et al. (1984), and which can produce the large horizontal electric fields given the presence of horizontal winds, of charged aerosols for which the positive and negative species are of slightly different mass, and of an atmospheric electrical conductivity which is relatively low ($<10^{-10}$ S/m). The electric field is a direct consequence of the current driven by mass dependent acceleration of the two charge species initially at rest in a collisional medium. This theory, if valid, along with the experimental findings of Hale and Maynard, offer encouragement for the reality of the V/m fields.

Although the theory of Curtis has only been directly applied to the large electric field region, noctilucent clouds (NLC) may offer a natural laboratory for assessing it. These clouds, which are the highest in our atmosphere, occur near the high latitude mesopause (~83km) during summer, when the mesopause can reach extremely low temperatures approaching 110°K. This environment provides two necessary ingredients, viz. aerosols and atmospheric dynamics, although the electrical conductivity is somewhat higher than at the lower altitudes where the large V/m electric fields are thought to occur. Nonetheless, the higher conductivity would simply cause smaller (but still measurable) electric field perturbations, provided all other quantities such as winds and particle characteristics were equivalent. In July, 1986, vector electric field measurements were made through a noctilucent cloud (cf. GOLDBERG, 1990) using the Maynard technique. All three components of electric field were observed to exhibit modulations, during cloud passage, implying that the cloud environment was responsible for electric field perturbations in both amplitude and direction, albeit smaller than those expected at lower altitudes in a region of lower electrical conductivity. Future measurements of this type in coordination with simultaneous measurements of winds and particular size within NLC's are needed to validate the Curtis' theory and increase our confidence in the reality of the reported V/m electric fields.

In addition to providing the NLC environment for the studies discussed above, the high latitude mesosphere may also contain critical features more amenable for the creation of large V/m electric fields. Although these apparent large electric fields have never been observed in an atmospheric region where the electrical conductivity is high ($> 10^{-10}$S/m), it is also true that the majority of their sightings has been at higher latitudes where this condition is more difficult to attain. A special rocket campaign, Projector Condor, conducted at the magnetic equator at Punta Lobos, Peru, in 1983, included payloads specifically designed for V/m electric fields in a quiet, low conductivity environment. Yet, with nine soundings over a 24 hour period it was unsuccessful in observing large fields of the type described here (CROSKEY et al., 1985). This result occurred in spite of the fact that heavy ions had been observed in excess of $10/cm^3$ (GOLDBERG et al., 1985; MITCHELL, 1986). It now seems that heavy ions and low electrical conductivity are necessary but sufficient requirements to create and maintain such fields, which is consistent with the CURTIS (1987) theory.

Furthermore, at least for horizontal electric fields, we have discussed that local neutral atmospheric dynamics such as horizontal winds (MAYNARD et al., 1984; CURTIS, 1987) can play an important role by forcing charge separation. At high latitudes, large horizontal winds, wind shears, vertical waves and local turbulence are more likely to be present than at lower latitudes, as evidenced by MST radar results which report a persistent region of reflecting layers between 60 and 80 km during winter, and another region above 80 km during summer. New in-situ rocket results during the Energy Budget, MAP-WINE, STATE, and MAE-3 scientific rocket programs have exhibited small scale turbulence as low as 3 meter scale size in the local plasma structure (e.g., THRANE et al., 1985, 1987; ULWICK et al., 1988; BLOOD et al., 1988; GOLDBERG et al., 1988). During STATE (FRITTS et al., 1988) and MAE-3 (GOLDBERG et al., 1988), which were conducted from Poker Flat, Alaska in June 1983 (summertime) and March 1985 (wintertime) respectively, large scale waves were observed in the charged and neutral atmospheric structure simultaneously, verifying the value of using the charged particle environment to study neutral atmospheric dynamics. Also, it was determined that the MST radar required daytime ionization in excess of that provided by solar radiations responsible for average daily ionization rates, in order to detect the neutral wave structure. These considerations would appear to make the high latitude middle atmosphere an important region in which to search for large V/m electric fields, and to study interactions between the charged and neutral atmosphere. It would also appear that the plasma structure provides an important function as a tracer for neutral atmospheric dynamical behaviour. This concept is further amplified in the following section dealing with stratospheric balloon measurements.

6.3 Stratospheric Balloon Results

Stratospheric balloon-borne experiments have contributed more data on MAE than any other in-situ experiment or technique. Balloon-borne payloads have collected thousands of hours of measurements of the vector electric field, conductivity and current density. Furthermore, sounding balloons have been used to measure vertical profiles of electrical parameters from the ground up to altitudes between 35 and 40 km. Over the years these data have given us a strong background understanding of the electrodynamics of the stratosphere, both as an independent region of interest within the middle atmosphere as well as providing a good lower boundary condition for mesospheric electrodynamical studies. The reader is referred to recent reviews (REID, 1986; HOLZWORTH, 1987) which discuss many of these balloon-borne measurements.

As mentioned earlier, until the early 1980's the middle atmosphere was considered to be basically electrically passive. Since the stratosphere is electrically coupled to the ionosphere by the conducting middle atmosphere, it has been common practice to use balloon-borne electric field measurements in studies designed specifically to address ionospheric and magnetospheric geophysical problems. Indeed, since the large scale ionospheric electric field maps with little attenuation down to the stratosphere, balloon payloads can be used to perform global averages with high time resolution of magnetospheric phenomena which cannot yet be done using satellites. Measurements made during MAP confirmed that mapping of the large scale, quasi-static electric field data between magnetically conjugate balloons and satellites produced excellent agreement between data sets (c.f. HOLZWORTH, 1987).

As the balloon-borne measurement data set grew, it became clear that the stratosphere could not adequately be modelled as a passive medium in which global averages of fields and conductivity could be readily substituted for measurements in actual case studies. With the advent of MAP, visibility of the interesting electrodynamical problems of the middle atmosphere also increased. At first, and to some extent throughout MAP, MAE projects were conducted independently but in parallel. In this review we consider the advances in MAE made during and parallel to MAP - independently of whether they came under the auspices of MAP. The most important new results in MAE due principally to balloon-borne experiments can be divided into five categories:

1. variability of fair weather conductivity,
2. global circuit variability,
3. thunderstorm and electrified cloud effects on fields and conductivity.
4. solar flare effects on current and conductivity,
5. a new source for stratospheric electric fields.

The following paragraphs discuss these in more detail.

6.3.1 Variability in the fair weather conductivity.

To understand and model the electric coupling between ground and ionosphere requires accurate measurement of the atmospheric conductivity. The traditional approach to studying the stratosphere-ionosphere linkage was to begin with a model conductivity profile with altitude. In most models (e.g. PARK and DEJNAKARINTRA, 1973) the mapping of fields and currents depended only on the conductivity scale height and not absolute values. Until recently the state of this art was to take all the available data in a format such as our figure 1 and draw a straight line (exponential fit on this log-linear plot) to estimate the average conductivity scale height. This approach failed in specific cases such as the lack of a prediction of significant electric fields in the ionosphere due to lightning, e.g. KELLEY et al., (1985) measured lightning signatures more than two orders of magnitude larger than predicted at 150 km altitude. Thus, we have become more aware of the need to use the actual conductivity profile in case studies of electrodynamical coupling. Possible effects on atmospheric conductivity due to volcanic emissions have been studied by GRINGEL et al., (1986), GUPTA and NAYARAN (1987), and SOMAYAJULU et. al., (1988). Significant differences between positive and negative polar conductivities have been reported by ROSEN et al. (1982), NORVILLE and HOLZWORTH (1987), GRINGEL et al. (1986) and BEIG et al. (1989) which may, in some cases be related to differences in ion mobilities (c.f. ROSEN et al., 1985). BYRNE et al, (1988) have recently reported results from nine stratospheric balloon flights from which conductivity variations in latitude and altitude are summarised.

6.3.2 Global circuit variability

Although C.T.R. Wilson proposed the basis for global electrical circuit in the early years of this century (see references in CHALMERS, 1967), we still have not determined that the current source is indeed thunderstorms and not some other (possibly related) phenomenon. Furthermore, most models of the global circuit have carefully included the orography but have been conducted with a static source function (c.f. HAYS and ROBLE, 1979). Measurements of the in-situ atmospheric current density in fair weather have now been used to show that the global circuit is anything but steady or even repeatable on a day to day basis (HOLZWORTH et al., 1984, NORVILLE and HOLZWORTH, 1987). In these papers it is shown that, while the average daily variation of the global scale current density is similar to the Carnegie curve (c.f. CHALMERS 1967), there are real variations on time scales of tens of minutes which can be more than a factor of two different from the average daily variation. Thus, it is no wonder that individual case studies of the electrodynamics of non-severe weather (such as electrified clouds or fog) can be difficult to interpret without any knowledge of the global circuit variation.

6.3.3 Thunderstorm and electrified cloud effects on fields and conductivity

Much of our present understanding of the upward electrical coupling from thunderstorms into the middle atmosphere and ionosphere comes from stratospheric balloon measurements. In experiments to study ionospheric and magnetospheric questions there have been hundreds of balloon flights into the stratosphere to make vector electric field measurements. In many of the earlier flights it was found that on the average about 10% of the data were totally dominated by thunderstorms. These data were originally considered to be a noise signal for the space science research. However, it was soon determined that those data may have valuable information on the tropospheric electrodynamics as well as electrodynamical coupling to the ionosphere. A paper reviewing many of these data which, prior to 1981 had remained unpublished was given by HOLZWORTH (1981).

Several recent papers indicate that thunderstorms may be responsible for significant atmospheric conductivity variations in the stratosphere. Initially BERING et al. (1980) reported that the conductivity in the stratosphere over a thunderstorm was modified by a factor of two with respect to the ambient conductivity. For the largest storms, the conductivity seems to increase in many cases (c.f. HOLZWORTH, 1987). This presents the possibility that the electrodynamical coupling between tropopause and ionosphere may be strongly controlled by time varying conductivity and not just source variations. This experimental observation was recently confirmed by PINTO et al. (1988).

There has been significant effort to identify electrical effects in the stratosphere from both thunderstorms as well as electrified clouds. By electrified cloud we mean any cloud which produces significant electrical perturbations but from which no lightning was identified (c.f. HOLZWORTH, 1981). Barcus et al. (1986) measured important effects from electrified clouds in large arctic storms. With the Atlas Centaur 67 NASA rocket failure due to vehicle triggered lighting (26 March 1987), there is little doubt that thunderstorms and electrified clouds will be a major topic of continuing research support.

6.3.4 Solar flare effects on currents and conductivity

It is well known that solar flares emit both electromagnetic and corpuscular radiation which are directly received at the surface of the earth. A proton must have about 10^9 eV to reach the surface. These solar cosmic rays are also known to have an important effect on atmospheric conductivity (REID, 1986). However, recently it was reported that during a solar flare the global circuit current density appeared to be unbalanced in a fashion which could not be explained by standard global theories (HOLZWORTH et al., 1987). The work of REAGAN et al. (1983) indicate that there is a significant current just due to the solar protons themselves well down into the stratosphere which must be also considered in global models of flare effects. Recently, BAKER et al. (1987)

have reported satellite observations of intense relativistic fluxes at geostationary altitude, exhibiting large fluxes up to 10 MeV. Should these fluxes reach atmospheric depths, they could significantly affect atmospheric electrodynamic characteristics down to stratospheric levels, and must be considered in future research activities.

6.3.5 A new source for stratospheric electric fields.

It was recently reported (HOLZWORTH, 1989) that data from long duration balloons in the stratosphere suggest that a new source of electric field is dominant at middle latitudes in fair weather. The characteristics of this field are that it is quite turbulent with linear polarization, the vector direction rotates counter clockwise (in the southern hemisphere) with the period of the inertial wave, given by [12 hour/sin (latitude)], associated with geostrophic adjustment. This field has a magnitude between 10 and 50 mV/m in the horizontal electric field component and may represent a significant perturbation to interpreting midlatitude balloon measurements in terms of ionospheric dynamo phenomena.

6.4 Tropospheric Lightning Effects

The role of lightning as a VLF radio source for magnetospheric electron precipitation has be analyzed theoretically (CHANG and INAN, 1985a,b) and studied with rockets (RYCROFT, 1973; GOLDBERG et al., 1986; 1987), satellites (VOSS et al., 1984) and ground based receivers (INAN et al., 1985). In most cases the evidence for lightning-induced VLF was provided by measurement or radio whistlers, which are normally considered to originate from lightning flashes. Early theoretical treatments considered the wave-particle interactions to occur close to the magnetic equator, whereby the ducted whistler travels along the magnetic field line and alters the energetic pitch angle distribution through an electron cyclotron resonance process (ECR) near the magnetic equator (c.f. SCHULZ and LANZEROTTI, 1974 for a review of this topic). The ECR process has been confirmed experimentally, directly by RYCROFT (1973) and indirectly by Rosenberg et al. (1971) and Foster and Rosenberg (1976). More recent work by CHANG et al., (1983), TKALCEVIC et. al. (1984), CHANG and INAN (1983) and INAN et al. (1984) has extended this analysis to regions outside the equatorial zone to all magnetic latitudes along field lines, containing energetic electron fluxes. In addition, GOLDBERG et al. (1987) have shown evidence for at least one competing process (currently undefined) which may contribute energetic electrons with equivalent energy fluxes to those produced by the ECR process.

The middle atmosphere must influence the path of the VLF waves produced by lightning on route to the magnetosphere. Little is known about the energy transfer processes through this region, although it is clear that middle atmosphere can regulate them up to such extremes as full transmission or absorption. During the WIPP (Wave Induced Particle Precipitation) program conducted at Wallops Island, Virginia in July, 1987, several rockets were launched under good lightning conditions, but with no observation of obvious electron bursts associated with individual lightning flashes. Analysis of some of the data with signal-to-noise processing has yielded evidence for very weak bursts, far smaller than anticipated from the theoretical results. For these reasons, both the role of the middle atmosphere as a transmission agent, as well as the types of wave-plasma processes induced by the received energy in the magnetosphere must be studied in future experiments.

Verification that high intensities of energetic electrons are reaching atmospheric levels can be determined through use of A Schumann resonance monitoring station (SENTMAN, 1983), which provides continuous information regarding the intensity and phasing of ELF resonances within the Earth-ionosphere cavity, as a means to determine changes in global thunderstorm activity, atmospheric electrical conductivity, etc. The question of need for and development of a "geoelectric" index has been the subject of several scientific meetings, working groups, and publications (e.g. HOLZWORTH and VOLLAND, 1986). Earlier proposed measurements of ionospheric potential, air-Earth currents, and other atmospheric electrical parameters have all been opposed because of difficulties with both the measurement techniques and data interpretation. The use of a network of ELF stations could be a new approach to this problem, by offering an inexpensive method to observe global (and local) variations in key parameters such as lightning activity. Such data accumulated on a regular basis would strongly assist towards the evaluation of the feasibility and need for a "geoelectric" index.

6.5 Conclusions

Middle atmospheric electrodynamics as a discipline was largely unknown prior to the MAP era, but now holds a position of increasing interest to the scientific community. New results now imply that this discipline may yield important information regarding coupling between the upper and lower atmosphere, including interactions involving the magnetosphere and ionosphere. Within the middle atmosphere, it has already been shown that the charged and neutral atmosphere often reflect similar dynamical structure, making plasma measurements a valuable tool for tracking neutral atmospheric dynamical behaviour. Of course, progress in the field has been rather modest, considering the need for in situ measurements, which are restricted primarily to rockets and balloons.

We must resolve questions regarding the reality of the reported large V/m electric fields in the lower mesosphere. Further experiments are needed to evaluate the V/m fields, which if real, offer a feasible mechanism for coupling electrodynamic effects down to tropospheric altitudes. Generation of such fields may imply generation of electrical currents which could significantly contribute to the global electrical circuit. Such contributions would in turn be modulated by incoming radiations during high latitude disturbances such as geomagnetic storms, relativistic electron precipitation events, solar proton events, etc. These could induce electrical conductivity enhancements to lower atmospheric altitudes thereby affecting the entire electrical environment of that region, including reduction or elimination of the V/m electric fields. The importance of such effects is dependent on the frequency and extent of such fields, which must still be determined along with their reality. New experimental and theoretical results have improved our confidence on the latter, and new experiments are now being designed to assess the recently proposed theoretical ideas. Some of these planned on an international scale currently include SuperCamp, NLC-90, and MAC-Rep, all of which will be used to test some of the new theoretical and experimental findings in this field.

The measurement of stratospheric electrodynamic properties has also progressed during the MAP era. New technological developments such as superpressure balloons now make long-term detailed study of this region under a wide range of geophysical conditions, a distinct possibility. New results, such as the rotation of the horizontal stratospheric electric field at fixed phase with respect to quasi-inertial neutral atmospheric waves, show that the electrodynamical structure of this region is far more complicated than originally predicted.

Tropospheric lightning also presents an intriguing source for electrodynamic coupling involving the middle atmosphere. Results obtained during MAP show that earlier theoretical predictions of magnetospheric electron precipitation induced by lightning apparently occur, but not with the intensity originally anticipated. New experimental evidence also indicates that more than one physical process may occur during lightning induced wave/plasma interactions within the magnetosphere, although new experiments must be designed to identify the specific physical processes in effect. One aspect of this field considers monitoring of Schumann ELF resonances within the Earth–ionosphere cavity as a means to monitor global lightning, and perhaps provide a means to develop a useful "geoelectric" index. Research in this area is just in the preliminary stage, but already offers promise for significant advances in the near future.

We have attempted to convince the reader that the middle atmosphere is electrodynamically important for global electrical systems; yet to a large extent remains unexplored. We believe it to be necessary and indeed now justified to mount a series of comprehensive experiments to investigate many of the discussed phenomena in greater detail. Due to the inaccessibility of the middle atmosphere (especially its electrical structure) to remote sensing, this must be accomplished with an increased number of rocket and high altitude balloon flights dedicated to MAE objectives. Specifically, investigators should be focussed on: resolving the large (V/m) electric field controversy, comprehensive experimental determinations of the atmospheric electrical conductivity profile in space and time, studies of tropospheric electric field/current sources including thunderstorms and the practically uninvestigated "electrified" cloud, and comprehensive studies of aerosols at high altitudes. All of these investigations must be co-ordinated with ongoing theoretical studies. We also suggest that when feasible, all such direct MAE investigations be conducted in close co-ordination with other relevant programs such as NASA's lightning mapper satellite, which would be mutually and strongly beneficial to both areas of research.

6.6 Recommendations

(1) Central Middle Atmosphere (45 to 85 km)

We recommend that an experimental program be conducted to concentrate on central middle atmospheric electrodynamics between the altitudes of 45 to 85 km. Sparse information exists for this domain at best. We need to obtain the basic "numbers" about this region, since it is the region about which we know the least, but which plays a controlling influence in many phases of the electrodynamical coupling between stratosphere and ionosphere. It is also the region in which the electric currents switch from being carried basically by electrons (upper part) to ions of both polarities (lower). It is the region which is only directly accessible by rockets and not by either balloons or satellites. Furthermore, even radars cannot see this region very well because the neutral density is too low for significant reflection off index of refraction variations and the electron density is too low for significant thermal electron density reflections. Since we know that dramatic conductivity variations are expected in the middle atmosphere from 45 to 85 km (see figure 6.1 for a 5 order of magnitude spread at 50 km altitude!) and we also know that neutral winds can be significant, we have all the ingredients for significant electrical generation and major current perturbations. We propose that NASA, NSF, ESA, and other agencies begin a major focus of multiple rocket flights to obtain the needed data set for beginning modelling of the region 45 to 85 km altitude globally.

(2) Conductivity-Connectivity.

A major key to modelling the electrodynamical coupling between ionosphere and lower atmosphere is accurate knowledge of the conductivity profile. Global modelling requires multiple local measurements conducted concurrently in time. Knowledge of the variation of atmospheric conductivity scale height and absolute value is needed at all locations. We recommend that a major effort be initiated to obtain accurate conductivity profiles from the troposphere to the ionosphere from as many locations as possible during every season.

(3) Electrified Clouds.

NASA's Atlas-Centaur rocket AC67 was destroyed when it triggered a lightning stroke. The environment through which is was launched was an electrified cloud layer, which prior to the triggered lightning had not produced any lightning. This type of cloud is very common - yet we know next to nothing about it. Clearly electrified clouds produce important signals in the middle atmosphere and may be an important source of global circuit current. We just do not know enough to be quantitative at this point. We recommend that emphasis be placed on quantifying and modelling the effects of electrified clouds on MAE and the global circuit. A simple definition of electrified cloud for this purpose is any cloud which produces measurable electrical effects but from which no lightning has been detected.

(4) Aerosols at High Altitudes.

Aerosols as large as 10^3 amu have been inferred from mobility measurements between 70 and 90 km. How do they get there? What molecules are they? What are their electrical/chemical properties? How do they effect MAE? Are they related to noctilucent clouds? If so how? We recommend that this interesting phenomenon be addressed with a focused experimental program of optical, electrical and mass spectrometer measurements.

(5) NASA Lightning Mapper.
While we presently have some satellite measurements which can quantify the external plasma/electrodynamical input to the magnetosphere (e.g. any measuring solar wind parameters), there exists no quantitative measure of the input from below. We strongly urge NASA to grant a new start to the geostationary lightning mapper as a necessary instrument for the study of the dynamics and spatial distribution of one of the two main sources of electrification of the middle atmosphere - thunderstorms.

(6) MAE Response to High Energy Electron Showers.
Recent studies of relativistic electron fluxes from geosynchronous satellites imply the frequent penetration of high energy electron showers within the high latitude atmosphere for 1-5 years following solar maximum. Such showers can severely modulate middle atmospheric electrodynamical structure including conductivity, ionization, and electric field characteristics. These changes could in turn, have profound effects on the global electric circuit, which relates to ionospheric-atmospheric coupling. We recommend a concentrated effort with rockets and balloons to investigate the electrodynamical effects of these showers, which are anticipated to begin again by 1990.

(7) Large (V/m) Electric Fields.
The large (V/m) electric fields which have been reported in the lower mesosphere on an occasional basis require further study to determine their reality and validity. Now that new theories to explain such fields have been proposed, it is possible to design experiments which center on the proposed causal elements, e.g. winds, charged aerosols, low electrical conductivity, etc. We recommend that rocket and balloon flight programs be conducted to test the proposed mechanisms, and to learn more concerning the validity of the measurement techniques from intercomparisons between various types of instruments. As a corollary, work should continue to establish the extent (in space and time) of such fields (if real) and their potential influence on the global system.

(8) Global Electrodynamical Circuit.
In recent years experiments have shown that the global circuit is probably variable on both short and long time scales, relative to the "expected" diurnal variations. The source of these variations has yet to be identified and could be due to the temporal variability of the sources and/or variations in the effective impedance of different circuit elements. We suspect that the simple model of a single source type such as thunderstorms pumping current into the upper atmosphere (the Wilson model) is a gross oversimplification. For instance, this model cannot explain the reported large scale differences between polar and low latitude current densities during solar flares. We recommend that adequate samples of current density data be collected using either ground based measurements (with large scale averaging to avoid local turbulence effects) or stratospheric balloon-borne measurements to obtain an empirical model of the global return current density. The modelling effort would be combined with other MAE investigations, particularly under recommendations #2 and #5.

REFERENCES

Ajello, J.M., Stewart, A.I., Thomas, G.E., and Graps, A. Solar cycle study of Interplanetary Lyman-Alpha Variations: Pioneer Venus orbiter sky background results', Ap. J., 317, 964-986, 1987.

Andrews, D.G., Holton, J.R., and Leovy, C.B. Middle Atmosphere Dynamics, Academic Press, pp 489, 1987.

Arijs, E., and Brasseur, G. Acentonitrile in the stratosphere and implications for positive ion composition, J. Geophys. Res., 91, 4003-4016, 1986.

Arijs, E., Nevjans,, Frederick, P. and Ingels, J., Stratospheric negative ion composition measurements ion abundances and related trace gas detection, J. Atmos. Terr. Phys., 44, 681-694, 1982.

Arnold, F., and Qiu, S. Upper stratosphere negative ion composition measurements and inferred trace gas abundances, Planet. Space Sci., 32, 69-177, 1984.

Arnold, F., and Viggiano, A.A. Combined mass spectrometric composition measurements of positive and negative ions in the lower ionosphere - I Positive ions. Planet. Space Sci., 30, 1295-1305, 1982.

Arnold, F., VIggiano, A.A. and Ferguson E.E. Combined mass spectrometric composition measurements of positive and negative ions in the lower ionosphere - II Negative ions, Planet. Space Sci., 30, 1307-1314, 1982.

Baker, D.N., Blake, J.B., Gorney, D.J., Higlia, P.R., Klebesadel, R.W. and King, J.H. Highly relativistic magnetospheric electrons; A role in coupling to the middle atmosphere?, Geophys. Res. Letts., 14, 1027, 1987.

Balsley, B.B, and Gage, K.S.. The MST radar technique: Potential for middle atmospheric studies, Pure App. Geophys., 118, 452 1980.

Barcus, J.R, Iversen, I.B and Stauning P. Observations of the electric field in the stratosphere over an Arctic storm system, J. Geophys. Res., 91, 9881-9892, 1986.

Barnett, J.J., and Corney, M., Middle atmospher reference model derived from satellite data, In Handbook for MAP Vol 16, (ed. K. Labitzke, J.J. Barnett, and B. Edwards) 47-85, 1985.

Beig, G., Sidhu, J.S., Das, S.R., and Charkrabarty, D.K., Balloon-borne measurements of stratospheric ion conductivity profile at low latitude. J. Geophys. Res., 94, 11,070-11073, 1989.

Bering, E.A., Rosenberg, T.J., Benbrook, J.R., Detrick, D., Mathews D.L., Rycroft, M.J., Saunders, M.A. and Sheldon, W.R. Electric fields, electron precipitation, and VLF radiation, during a simultaneous magnetospheric substorm and atmospheric thunderstorm. J. Geophys. Res., 85, 55-72, 1980.

Beynon, W.J.G., Williams, E.R., Arnold, F., Krankowsky, D., Bain, W.C. and Dickinson, P.G.H.G., D-region rocket measurements in winter anomaly conditions. Nature 216, 118-199, 1976.

Blood, S.P., Mitchell, J.D., Croskey, C.L., Raymund, T.D., Thrane, E.V., Blix, T.A., Hoppe, U.P., Fritts, D.C. and Schmidlin, F.J. Studies of high-latitude mesospheric turbulence by radar and rocket. 2: measurements of small-scale turbulence. J. Atmos. Terr. Phys. 50, 963-976, 1988.

Bossy, J., Solar indices and Solar U.V. - Irradiances, Planet. Space Sci., 31, 977-985, 1983.

Bossy, J., and Nicolet, M., On the variability of Lyman-Alpha with Solar activity, Planet. Space Sci., 29, 907-914, 1981.

Boville, B.A., and Randell, W., Observations and simulation of the variability of the stratosphere and troposphere in January, J. Atmos. Sci., 43, 3015-3034, 1986.

Bragin, Yu, A., Tyutin, A.A., Kocheev, A.A. and Tyutin, A.A. Direct measurement of the atmospheric vertical electric field intensity up to 80 km. Cosmic Res. 12, 279-282, 1974.

Brasseur, G. and Chatel, A. Modelling of stratospheric ions: A first attempt, Ann. Geophys. 1, 173-185, 1983.

Brasseur, G., and De Baets, P. Ions in the mesosphere and lower thermosphere: A two dimensional model, J. Geophys. Res., 91, 4025-4046, 1986.

Brasseur, G., and Simon, P., Stratospheric Chemical and Thermal Response to Long-term Variability in Solar U.V. Irradiance, J. Geophys. Res., 86, 7343-7362, 1981.

Byrne, G.J., Benbrook, J.R. Bering, E.A., Oro, D., Seubert C.O. and Sheldon, W.R. Observations of the stratospheric conductivity and its variation at three latitudes. J. Geophys. Res., 93, 3879-3891, 1988.

Cariolle, D., and Deque, M. Southern hemisphere medium-scale waves and vertical ozone disturbances in a spectral general circulation model, J. Geophys. Res., 91, 10,825-10,846, 1986.

Callis, L.B., Bougher, R.E, and Lambeth, J.D., The stratosphere: climatologies of the radiative heating and cooling rates and the diabatically diagnosed net circulation fields, J. Geophys. Res., 92, 5585-5608, 1987.

Chalmers, J.A. Atmospheric Electricity, Pergamon, New York, 1967.

Chang, H.C., and Inan, U.S. A theoretical study of observed correlations between whistler mode waves and energetic electron precipitation events in the magnetosphere. J. Geophys. Res., 88, 10,053-10,058, 1983.

Chang, H.C. and Inan, U.S. Lightning-induced electron precipitation from the magnetosphere. J. Geophys. Res. 90, 1531, 1985a.

Chang, H.C. and Inan, U.S. Test partical modeling of wave-induced energetic electron precipitation, J. Geophys. Res., 90, 6409-6418, 1985b.

Chang, H.C., Inan, U.S. and Bell, T.F. Energetic electron precipitation due to gyroresonant interactions in the magnetosphere involving coherent VLF waves with slowly varying frequency. J. Geophys. Res., 88, 7037-7050, 1983.

Croskey, C.L., Hale, L.C., Mitchell, J.D., Muha, D. and Maynard, N.C. A diurnal study of the electrical structure of the equatorial middle atmosphere. J. Atmos. Terr. Phys. 47, 835-844, 1985.

Curtis, S.A. Current-driven large horizontal electric fields in the middle atmosphere. In IAGA Abstracts, CEDAR Symposium, IUGG 19th General Assembly, Vancouver, B.C., Canada, 1987.

Dickinson, R.E., Infrared radiative cooling in the mesosphere and lower thermosphere, J. Atmos. Terr. Phys., 46, 995-1008, 1984.

Donnelly, R.F., Temporal trends of Solar EUV and UV full-disk fluxes, Solar Phys., 109, 37-58, 1987.

Donnelly, R.F., Uniformity in Solar U.V. flux variations important to the Stratosphere, Ann. Geophysicae, 6, 417-424, 1988.

Donnelly, R.F., Hinteregger, H.E., and Heath, D.F., Temporal variations of Solar EUV, UV, and 10,830-Å radiations, J. Geophys. Res., 91, 5567-5578, 1986.

Dunkerton, T., On the mean meridional mass motion of the stratosphere and mesosphere, J. Atmos. Sci., 35, 2325-2333, 1978.

Eisele, F.L. Mc Daniel, E.W. Mass spectrometric study of tropospheric ions in the north-eastern and south-western United States. J. Geophys. Res., 91, 5813-5188, 1986.

Fairlie, T.D.A. and O'Neill, A., Aspects of the dynamics of the middle atmosphere inferred by using data from satellite and from a numerical model, Phil. Trans. Roy. Soc., A 323, 679-692, 1987.

Farman, J.C., Gardiner, G.B., and Shanklin, J.D., Large losses of total ozone in Antarctica reveal seasonal ClO_x/NO_x interaction, Nature, 315, 1398-1400, 1985.

Fels, S.B., J.D. Mahlman, M.D. Schwarzkopf and R.W. Sinclair, Stratospheric sensitivity to perturbations in ozone and carbon dioxide: Radiative and dynamical response, J. Atmos. Sci., 37, 2265-2297, 1980.

Fels, S.B., A parameterization of scale-dependent radiative damping rates in the middle atmosphere, J. Atmos. Sci., 39, 1141-1152, 1982.

Fels, S.B., The radiative damping of short vertical scale waves in the mesosphere, J. Atmos. Sci., 41, 1755-1764, 1984.

Forbes, J.M., Middle atmosphere tides, J. Atmos. Terr. Phys, 46, 1049-1067, 1984.

Foster, J.C. and Rosenberg, T.J., Electron precipitation and VLF emissions associated with cyclotron resonance interactions near the plasmapause. J. Geophys. Res., 81, 2183-2192, 1976.

Fritts, D.C. Gravity wave saturation in the middle atmosphere: A review of theory and observations, Rev. Geophys. Space Sci., 22, 275-308, 1984.

Fritts, D.C. Smith, S.A., Balsley, B.B. and Philbrick, C.R. Evidence of gravity wave saturation and local turbulence production in the summer mesosphere and lower thermosphere during the STATE experiment. J. Geophys. Res., 93, 7015-7025, 1988.

Ganguly, S. Observations of large negative ion zones around 88 km, J. Atmos. Terr. Phys., 46, 6332-636, 1984.

Garcia, R.R., and Solomon, S., The effect of breaking gravity waves on the dynamical and chemical composition of the mesosphere and lower thermosphere. J. Geophys. Res., 90, 3850-3868, 1985.

Gille, J.C. and Lyjak, L.V., Radiative heating and cooling rates in the middle atmosphere, J. Atmos. Sci., 43, 2215-2229, 1986.

Goldberg, R.A. Middle atmospheric electrodynamics: Status and future. J. Atmos. Terr. Phys., 46, 1083-1101, 1984.

Goldberg, R.A. Electrodynamics of the high latitude mesosphere. J. Geophys. Res. 94, 14,661-14,672, 1990.

Goldberg, R.A., Barcus, J.R. and Mitchell, J.D. Response of the middle atmosphere to Sco X-1. J. Atmos. Terr. Phys., 47, 845-852, 1985.

Goldberg, R.A., Barcus, J.R., Hale, L.C. and Curtis, S.A. Direct observation of magnetospheric electron precipitation by lightning. J. Atmos. Terr. Phys. 48, 293-299, 1986.

Goldberg, R.A., Curtis, S.A. and Barcus, J.R. Detailed spectral structure of magnetospheric electron bursts precipitated by lightning. J. Geophys. Res., 92, 2505-2513, 1987.

Goldberg, R.A., Fritts, D.C., Chou, H-G., Barcus, J.R. and Schmidlin, F.J. Studies of high latitude mesopheric turbulence by radar and rocket. 1: Energy deposition and wave structure, J. Atmos. Terr. Phys, 50, 951-961, 1988.

Gringel, W., Rosen, J.M. and Hoffmann, D.J. Electrical Structure from 0 to 30 km. In The Earth's Electrical Environment, ed. E.P. Krider and Roble, R.G.. National Academy Press, Washington, D.C., p. 166, 1986.

Grose, W.L., and Russell, J.M., The LIMB infrared monitor of the stratosphere experiment: description and performance, J. Geophys. Res., 89, 5125-5140, 1984.

Grose, W.L., Nealy, J.E., Turner, R.E., and Blackshear, W.T., Modelling and transport of chemically active constituents in the stratosphere. In Transport Processes in the Middle Atmosphere. (ed G. Visconti and R. Garcia) G. Reidel, pp. 229-250, 1987.

Gutpa, S.P. and Narayan. A balloon-borne measurements of ion conductivity in the low latitude stratosphere. Planet. Space Sci., 35, 439-443, 1987.

Haigh, J.D., and Pyle, J.A., Ozone perturbation experiments in a two-dimensional circulation model, Quart. J. Roy. Met. Soc., 108, 551-574, 1982.

Hale, L.C. Middle atmospheric electrical structure, dynamics and coupling, Adv. Space Res. 4, 175, 1984.

Hale, L.C., Croskey, C.L. and Mitchell, J.D. Measurements of middle-atmospheric electric fields and associated electrical conductivities. Geophys. Res. Let., 8, 927-930, 1981.

Hall, L.A., and Anderson, G.P., Instrumental effects on a proposed Mg 11 index of solar activity, Ann. Geophysicae, 6, 531-534, 1988.

Hamilton, K., and Mahlman, J.D., General circulation model simulation of the semmiannual oscillation of the tropical middle atmosphere, J. Atmos. Sci., 45, 3212-3235, 1988.

Hays. P.B. and Roble, R.G. A quasi-static model of global atmospheric electricity 1. The lower atmosphere. J. Geophys. Res., 84, 3291-3305, 1979.

Heath, D.F., in Proceedings of International Conference on Sun and Climate, Centre National d'Etudes Spatiales, Toulouse (France), p. 163, 1980.

Heath, D.F., and Schlesinger, B.M., The Mg 280-nm Doublet as a Monitor of changes in Solar Ultraviolet Irradiance, J. Geophys. Res., 91, 8672-8682, 1986.

Heroux, L., and Higgins, J.E., Summary of Full-disk Solar fluxes between 250 and 1940 Å, J. Geophys. Res., 82, 3307-3310, 1977.

Hitchman, M.H., and Brasseur, G., Rossby wave activity in a two-dimensional model: closure for wave driving and meridional eddy diffusivity, J. Geophys. Res., 93, 9504-9417, 1988.

Hirota, I., Climatology of gravity waves in the middle atmosphere, J. Atmos. Terr. Phys., 46, 767-773, 1984.

Hofmann, D.J., and Solomon, S., Ozone destruction through heterogeneous chemistry following the eruption of El Chichon, J. Geophys. Res., 94, 5029-5041, 1989.

Holton, J.R., and Lindzen, R.S., An updated theory for the quasi-bienniel cycle of the tropical stratosphere, J. Atmos. Sci., 29, 1076-1080, 1972.

Holzworth, R.H. High latitude stratospheric electrical measurements in fair and foul weather under various solar conditions. J. Atmos. Terr. Phys. 43, 1115-1125, 1981.

Holzworth, R.H. Electric fields in the middle atmosphere, Physica Scripta, T18, 298, 1987.

Holzworth, R.H. A new source for horizontal electric fields in the stratosphere. J. Geophys. Res., 94, 12,795-12,802, 1989

Holzworth, R.H. and Mozer, F.S. Direct evidence of solar flare modification of stratospheric electric fields. J. Geophys. Res. 84, 363-367, 1979.

Holzworth, R.H. Norville, K.W. and Williamson, P.R. Solar flare perturbations in stratospheric current systems. Geophys. Res. Lett., 14, 852-855, 1987.

Holzworth, R.H., Onsager, T., Kinter, P. and Powell, S. Planetary scale variability of the fair weather vertical electric field, Phys. Rev. Lett. 53, 1398-1401, 1984.

Holzworth, R.H. and Volland, H. Do we need a geoelectric index? EOS Trans. AGU, 67, 547-548, 1986.

Hunt, B.G., The impact of gravity wave drag and diurnal variability on the general cycle of the middle atmosphere, J. Met. Soc. Japan, 64, 1-16, 1986.

Inan, U.S. Carpenter, D.L., Helliwell, R.A. and Katsufrakis, J.P. Subionospheric VLF/LF phase perturbations produced by lightning-whistler induced particle precipitation, J. Geophys. Res., 90, 7457-7469, 1985.

Inan, U.S. Chang, H.C. and Helliwell, R.A. Electron precipitation zones around major ground-based VLF sources. J. Geophys. Res., 89, 2891-2906, 1984.

Jukes, M.M. and McIntyre, M.E., A high resolotion one-layer model of breaking planetary waves in the stratosphere, Nature, 328, 590-596, 1987.

Kebarle, P., Searles, S.K., Zolla, A. Scarborough, J. and Arshadi, M. The solvation of the hydrogen ion by water molecules in the gas phase. Heats and entropies of solvation of individual reactions: $H^+(H_2O)_{n-1} + H_2O$ $H^+(H_2O)_n$. J. Amer. Chem. Soc., 89, 6393-6399, 1967.

Keesee, R.G. Lee, N. and Castleman, A.W. Jr., Atmospheric negative ion hydration derived from laboratory results and comparison to rocket-borne measurements in the lower ionosphere, J. Geophys. Res., 84, 3719-3772, 1979.

Kelley, M.C. Middle atmospheric electrodynamics, Rev. Geophys. Space Sci., 21, 273, 1983.

Kelley, M.C., Siefring, C.L. and Pfaff, R.F. Jr. Large middle atmospheric electric fields, fact or fiction? Geophys. Res. Lett. 10, 733-736, 1983.

Kelley, M.C., Siefring, C.L., Pfaff, R.F., Kintner, P.M., Larsen, M., Green, R. Holzworth, R.H., Hale, L.C., Mitchell, J.D. and LeVine, D. Electrical measurements in the atmosphere and ionosphere over an active thunderstorm: 1. Campaign overview and initial ionospheric results. J. Geophys. Res., 90, 9815-9823, 1985.

Kiehl, J.T. and S. Solomon, On the radiative balance of the stratosphere, J. Atmos. Sci., 43, 1525-1534, 1986.

Labs, D., Neckel, H., Simon, P.C., and Thuillier, G., Ultraviolet Solar Irradiance measurement from 200 to 358 NM during Spacelab 1 Mission, Solar Phys., 107, 203-219, 1987.

Lean, J., Solar Ultraviolet Irradiance Variations: A Review, J. Geophys. Res., 92, 839-868, 1987.

Leovy, C.B., Sun, C.R., Hitchman, M.H., Remsberg, E.E., Russell, J.M., Gordley, L.L., Gille, J.C., and Lyjac, L.V., Transport of ozone in the middle stratosphere: Evidence for planetary wave breaking, J. Atmos. Sci., 42, 230-244, 1985.

Lindzen, R.S., Turbulence and stress owing to gravity wave and tidal breakdown, J. Geophys. Res., 86, 9707-9714, 1981.

Link, R., Chakrabarty, S., Gladstone, G.R., and McConnell, J.C., An analysis of satellite observations of the O I EUV Dayglow, J. Geophys. Res., 93, 2693-2714, 1988.

Mahlman, J.D., Andrews, D.G., Hartmann, D.L., Matsuno, T., and Murgatroyd, R.J., Transport of trace constituents in the stratosphere, in Dynamics of the Middle Atmosphere, (eds. J.R. Holton and T. Matsuno), pp 387-416, 1984

Mahlman, J.D., and Umscheid, L.J., Dynamics of the middle atmosphere: Successes and problems of the GFDL "SKYHI" general circulation model, In Dynamics of the Middle Atmosphere, (ed J.R. Holton and T. Matsuno) Terrapub, pp 501-525, 1984.

Mahlman, J.D., and Umscheid, L.J., Comprehensive modelling of the middle atmosphere: The influence of horizontal resolution, In Transport Processes in the Middle Atmosphere, (ed G. Visconti and R.R. Garcia), Reidel, pp. 251-266, 1987.

Manson, A.H., et al., Mean winds of the upper middle atmosphere (~70-110 km) from the global radar network:Comparisons with CIRA 72 and new rocket and satellite data, Adv. Space Res., 7, 143-153, 1987.

Matsuno, T., A dynamical model of the stratospheric sudden warming, J. Atmos. Sci., 28, 1479-1494, 1971.

Maynard, N.C.(editor), Middle Atmospheric Electrodynamics, NASA CP-2090, 1979.

Maynard, N.C. Middle atmospheric electric fields. In Proceedings of the 5th ESA-PAC Symposium on Rocket and Balloon Programs and Related Research, ESA SP 152, 1980.

Maynard, N.C. Measurement techniques for middle atmospheric electric fields. In Rocket Techniques, MAP Handbook, Volume 19, ed. by R.A. Goldberg, Urbana, Illinois, 1986.

Maynard, N.C., Croskey, C.L., Mitchell, J.D. and Hale, L.C. Measurement of volt/meter electrical fields in the middle atmosphere. Geophys. Res. Lett., 8, 923-926, 1981.

Maynard, N.C., Hale, L.C., Mitchell, J.D., Schmidlin, F.J., Goldberg, R.A., Barcus, F., Søraas, F. and Croskey, C.L. Electrical structure in the high latitude middle atmosphere. J. Atmos. Terr. Phys. 46, 807, 1984.

McIntyre, M.E., and Palmer, T.N., Breaking planetary waves in the stratosphere, Nature, 305, 593-600, 1983.

McIntyre, M.E., and Palmer, T.N., The 'surf zone' in the atmosphere, J. atmos. Sci., 46, 825-850, 1984.

Mentall, J.E., and Williams, D.E., Solar Ultraviolet Irradiances on December 7th, 1983, and December 10th, 1984, J. Geophys. Res., 93, 735-746, 1988.

Mentall, J.E.,, J.E. Frederick, J.E., and Herman, J.R., The Solar Irradiance from 200 to 330 nm, J. Geophys. Res., 86, 9881-9884, 1981.

Mentall, J.E., Guenther, B., and Williams, D., The Solar Spectral Irradiance between 150-200 nm, J. Geophys. Res., 90, 2265-2271, 1985.

Meyerott, R.E., Reagan J.B. and Joiner, R.G. The mobility and concentration of ions and the ionic conductivity in the lower stratosphere. J. Geophys. Res., 85, 1273-1278, 1980.

Mitchell, J.D. Rocket probe techniques for measuring bulk ion properties. In Rocket Techniques, MAP Handbook, Volume 19, ed. by R.A. Goldberg, Urbana, Illinois, 1986.

Mount, G.H., and Rottman, G.J., The Solar Spectral Irradiance 1200-3184 Å near Solar Maximum: July 15, 1980, J. Geophys. Res., 86, 9193-9198, 1981.

Mount, G.H., and Rottman, G.J.,, The Solar Absolute Spectral Irradiance 1150-3173 Å, May 17, 1982, J. Geophys. Res., 88, 5403-5410, 1983a.

Mount, G.H., and Rottman, G.J.,, The Solar Absolute Spectral Irradiance at 1216 Å and 1800-3173 Å: Jan 12, 1983, J. Geophys. Res., 88, 6807-6811, 1983b.

Mount, G.H., and Rottman, G.J.,, Solar Absolute Spectral Irradiance 118-300 nm: July 25, 1983, J. Geophys. Res., 90, 13031-13063, 1985.

Mount, G.H., Rottman, G.J., and Timothy, J.G., The Solar Spectral Irradiance 1200-2550 Å at Solar Maximum, J. Geophys. Res., 85, 4271-4274, 1980.

Mozer, F.S. Balloon measurements of vertical and horizontal electric fields. Pure App. Geophys., 84, 32, 1971.

Narcisi, R.S. and Bailey, A.D. Mass spectrometric measurements of positive ions at altitudes from 64 to 112 kilometers. J. Geophys. Res., 70, 3687-3700, 1965.

Narcisi, R.S. Mass spectrometer measurements in the ionosphere. Physics and Chemistry of the Upper Atmosphere, 171-183. Ed. B.M. McCormac, D. Reidel Pub. Co., Dordrecht, 1973.

Narcisi, R., Bailey A., Federico, G and Wlodyka. L.E. Positive and negative ion composition measurements in the D- and E-regions during the February 1979 solar eclipse, J. Atmos. Terr. Phys., 45, 461-478, 1983.

Neckel, H., and Labs, D., The Solar Radiation between 3300 and 12500 Å, Solar Phys., 90, 205-258, 1984.

Newman, P.A., Schoeberl, M.R., and Plumb, R.A., Horizontal mixing coefficients for two-dimensional chemical models calculated from National Meteorological Center data, J. Geophys. Res., 91, 7919-7924, 1986.

Nicolet, M. Contribution a'letude de la structure de l'ionosphere. Inst. Roy. Meteor. 19, 83-245, Belgium Mem. 1945.

Nicolet, M., and Kennes, R., Aeronomic problems of molecular oxygen photo dissociation -III. Solar spectral irradiances in the region of the O_2 Herzberg continuum, Schumann-Runge bands and continuum, Planet. Space Sci., 36, 1059-1068, 1988.

Norville, K.W. and Holzworth, R.H., Global circuit variability from multiple stratospheric electric field measurements, J. Geophys. Res., 92, 5685-5695, 1987.

O'Neill, A., and Pope, V.D., Simulations of linear and non-linear disturbances in the stratosphere, Quart. J. Roy. Met. Soc., 1988.

Oster, L., Solar Irradiance Variations, 2, Analysis of the Extreme Ultraviolet Measurements Onboard the Atmosphere Explorer E Satellite, J. Geophys. Res., 88, 9037-9052, 1983.

Park C. and Dejnakarintra, M. Penetration of thundercloud electric fields into the ionosphere and magnetosphere, 1. Middle and subauroral latitudes. J. Geophys. Res. 78, 6623-6633, 1973.

Pitcher, E.J., Malone, R.C., Ramanathan, V., Blackmon, M.L., Puri, K. and Bourke, W., January and July simulations with a spectral general circulation model, J. Atmos. Sci., 40, 580-604, 1983.

Pinto, I.R.C.A., Pinto, O. Jr., Gonzalez, W.D., Dutra, S.L.G., Wygant, J. and Mozer, F.S. Stratospheric electric field and conductivity measurements over electrified convective clouds in the South American region. J. Geophys. Res. 93, 709-715, 1988.

Pitari, G., and Visconti, G. Two-dimensional tracer transport: Derivation of residual mean circulation and eddy transport tensor from a 3-D model set, J.Geophys. Res., 90, 8019-8032, 1985.

Plumb, R.A., and Mahlman, J.D., The zonally-averaged transport characteristics of the GFDL general circulation/transport model, J. Atmos. Sci., 44, 298-327, 1987.

Prather, M.J., and Garcia, R.R., Global impact of the Antarctic ozone hole: simulations with a 3-D chemical transport model, Polar Ozone Workshop, Aspen, CO, 9-13 May, NASA Conference Publcation 10014, 1988.

Reagan, J.B., Meyerott, R.E., Evans, J.E., Imhoff, W.L. and Joiner R.G. The effects of energetic particle precipitation on the atmospheric electric circuit. J. Geophys. Res., 88, 3869-3878, 1983.

Reid, G.C. The production of water cluster positive ions in the quiet daytime D-region. Planet. Space Sci., 25, 275-290, 1977.

Reid, G.C. Electrical structure of the middle atmosphere. In The Earth's Electrical Environment, ed. Krider E.P. and Roble, R.G. National Academy Press, Washington, D.C. 1986.

Rind, D., Suozzo, R., Balachandron, N.K., Lakis, A., and Russel, G., The GISS global climate-middle atmosphere model. Part I: Model structure and climatology, J. Atmos. Sci., 45, 329-370, 1988.

Rosen, J.M., Hoffmann, D.J., Gringle, W., Berlinsli, J., Michnowski, S., Morita, Y., Ogawa, T. and Olson, D. Results of an international workshop on atmospheric electrical measurements. J. Geophys. Res. 87, 1219-1227, 1982.

Rosen, J.M., Hoffmann, D.J. and Gringel, W. Measurement of ion mobility to 30 km. J. Geophys. Res., 90, 5876-5884, 1985.

Rosenberg, T.J., Helliwell R.A. .and Katsufrakis, J.P. Electron precipitation associated with discrete very-low-frequency emissions. J. Geophys. Res., 76, 8445-8452, 1971.

Rosenfield, J.E., Schoeberl, M.R., and Geller, M.A., A computation of the stratospheric diabatic circulation using an accurate radiative transfer model, J. Atmos. Sci., 44, 859-876, 1987.

Rottman, G.J.,, Rocket Measurements of the Solar Spectral Irradiance During Solar Minimum, 1972-1977, J. Geophys. Res., 86, 6697-6705, 1981.

Rottman, G.J.,, in Proceedings of the Workshop on Solar Radiation Output Variation, Boulder, Colorado (USA) p. 71, 1987.

Rottman, G.J., Adv. Space Res. to be published 1989.

Rycroft, M., Enhanced energetic electron intensities at 100 km altitude and a whistler propagating through the plasmasphere. Planet. Space Sci., 21, 239, 1973.

Schulz, M., and Lanzerotti, L., Particle Diffusion in the Radiation Belt, Springer-Verlag, New York, 1974.

Sentman, D.D. Schumann resonance effects of electrical conductivity perturbations in an exponential atmospheric-ionospheric profile. J. Atmos. Terr. Phys. 45, 55-65, 1983.

Simon, P.C., Irradiation Solar flux measurements between 120 and 400 nm. Current position and future needs. Planet. Space Sci., 26, 355, 1978.

Simon, P.C., Solar Irradiance between 120 and 400 nm and its variations, Solar Phys., 74, 273-291, 1981.

Simon, P.C., and Brasseur, G., Photodissociation effects of Solar U.V. Radiation, Planet. Space Sci., 31, 987-999, 1983.

Smith, L.G. and Royrvik, O. Electron-density irregularities in the day-time equatorial ionosphere. J. Atmos. Terr. Phys. 47, 813-824, 1985.

Smith, S.A., Fritts, D.C., and VanZandt, T.E., Evidence of a saturation spectrum of atmospheric gravity waves, J. Atmos. Sci., 44, 1404-1410, 1987.

Solomon, S., J.T. Kiehl, R.R. Garcia and W. Grose, Tracer transport by the diabatic circulation deduced from satellite observations, J. Atmos. Sci., 43, 1603-1617, 1986.

Somayajulu, Y., Garg, S.C., John T. and Zalpuri, K.S. Effects of volcanic debris on stratospheric ion conductivity: Nevado Del Ruis eruption event. COSPAR Abstracts, Paper 6.6.11, Espoo, Finland, 1988.

Swider, W. Ionic mobility of the middle atmosphere. Adv. Space Res., 4, 29-32. 1984.

Swider, W. Electron loss and the determination of electron concentrations in the D-region. Pure Appl. Geophys., 127, 403-414, 1988a.

Swider, W. Ionic Mobility, mean mass and conductivity in the middle atmosphere from ground level to 70 km, Rad. Sci., 23, 389-399, 1988b.

Swider, W. and Narcisi, R.S. A study of the night-time D-region. J. Geophys. Res., 80, 655-664, 1975.

Swider, W. and Narcisi, R.S. Steady-state model of the D-region during the February 1979 eclipse. J. Atmos. Terr. Phys. 45, 493-498, 1983.

Swider, W., Keneshea, T.J. and Foley, C.I. An SPE-disturbed D-region model. Planet Space Sci., 26, 883-892, 1978.

Tanaka, Y., Ogawa, T., and Kodama, M. Stratospheric electric fields and current measured at Syowa Station, Antarctica-1. The vertical component. J. Atmos. Terr. Phys. 39, 523-529, 1977.

Thrane, E.V., Andreassen, Ø., Blix, T., Grandal, B., Brekke, A., Philbrick, C.R., Schmidlin, F.J., Widdel H.U., Widdel, U., von Zahn and Lübken, F.J. Neutral air turbulence in the upper atmosphere observed during the Energy Budget Campaign. J. Atmos. Terr. Phys., 47, 243-264, 1985.

Thrane, E.V., Blix, T.A., Hall, C., Hansen, T.L., von Zahn, U., Meyer, W, Czechowsky, P., Schmidt, G., Widdel, H.U. and Neumann, A. Small scale structure and turbulence in the mesosphere and lower thermosphere at high latitudes in winter. J. Atmos. Terr. Phys., 49, 751-763, 1987.

Tkalcevic, S., Inan, U.S. and Helliwell, R.A. Nolinear pitch angle scattering and trapping of energetic particles during Landau resonance interactions with whistler mode waves. J. Geophys. Res. 89, 10,813-10,826, 1984.

Tsuda, T., Kato, S., Manson, A.H., and Meek, C.E., Characteristics of semidiurnal tides observed by the Kyoto meteor radar and Saskatoon Medium-Frequency radar, J. Geophys. Res., 93, 7027-7036, 1988.

Tung, K.K, Modelling of tracer transport in the middle atmosphere, in Dynamics of the Middle Atmosphere, (eds. J.R. Holton and T. Matsuno), pp 417-444, 1984.

Tung, K.K., A coiupled model of zonally averaged dynamics, radiation and chemistry, in Transport Process in the Middle Atmosphere, (eds. G. Visconti and R.R. Garcia), pp 183-198, 1987.

Tyutin, A.A. Mesospheric maximum of the electric field strength. Cosmic Res., 14, 132, 1976.

Ulwick, J.C., Baker, K.D., Kelley, M.C., Balsley B.B. and Ecklund, W.L. Comparison of Simultaneous MST radar and electron density probe measurements during STATE. J. Geophys. Res. 93, 6989-7000, 1988.

Vial, F., Numerical simulations of atmospheric tides for solstice conditions, J. Geophys. Res., 91, 8955-8969, 1986.

Viggiano, A.A., Schlager, H. and Arnold F. Stratospheric negative ions - detailed height profiles. Planet. Space Sci., 31, 813-820, 1983.

Vincent, R.A., Tsuda, T., and Kato, S., A comapritive study of mesospheric solar tides observed at Adelaide and Kyoto, J. Geophys. Res., 93, 669-708, 1988.

Voss, H.D., Imhof, W.L., Mobilia, J., Gaines, E.E., Walt, M., Inan, U.S., Helliwell, R.A., Carpenter, D.L., Katsufrakis, J.P. and Chang, H.C. Lightning induced electron precipitation. Nature, 312, 740, 1984.

WMO, World Meteorological Organization: The Stratosphere 1981. Theory and Measurements. Global Ozone Research and Monitoring Project Report No. 11, 516 pp, 1982.

WMO, World Meteorological Organization: Atmospheric Ozone 1985. Global Ozone Research and Monitoring Project Report No. 16, 1986.

Ziereis, H., and Arnold, F. Gaseous ammonia and ammonium ions in the free troposphere. Nature, 321, 503-505, 1986.

MAP HISTORY

Middle Atmosphere Program, 1982 - 1985
Middle Atmosphere Cooperation, 1986 - 1988
Middle Atmosphere Study, 1989 - 1990

ORIGINAL STEERING COMMITTEE
S. A. Bowhill, SCOSTEP, Chairman
K. Labitzke, COSPAR, Vice Chairman
C. H. Liu, SCOSTEP, Secretary
R. D. Bojkov, WMO
A. D. Danilov, COSPAR
J. C. Gille, COSPAR
J. B. Gregory, SCOSTEP
I. Hirota, IUGG/IAMAP
J. W. King, URSI
L. R. Megill, IUGG/IAGA
R. J. Murgatroyd, IUGG/IAMAP
T. Nagata, SCAR
P. C. Simon, IAU
J. Taubenheim, IUGG/IAGA
T. E. VanZandt, URSI
M. Wada, IUPAP

ORIGINAL STANDING COMMITTEES
Data Management, G. Hartmann, Chairman
Dynamics Calendar, T. E. VanZandt, Chairman
Publications, C. F. Sechrist, Chairman

PRESENT STEERING COMMITTEE
S. A. Bowhill, SCOSTEP, Chairman
K. Labitzke, COSPAR, Vice Chairman
C. H. Liu, SCOSTEP, Secretary
H. S. Ahluwalia, IUPAP
R. D. Bojkov, WMO
A. D. Danilov, COSPAR
J. C. Gille, COSPAR
I. Hirota, IUGG/IAMAP
A. H. Manson, SCOSTEP
T. Nagata, SCAR
R. G. Roper, IAMAP
P. C. Simon, IAU
J. Taubenheim, IUGG/IAGA
T. E. VanZandt, URSI
R. A. Vincent, URSI

PRESENT STANDING COMMITTEES
Data Management,
G. Hartmann, I. Hirota, Co-Chairmen
Publications, Belva Edwards, Chairman

MAP REGIONAL CONSULTATIVE GROUP
Europe, M. L. Chanin, Chairman

ICSU ADHERENTS ACTIVE IN MAP AND REPRESENTATIVES

Argentina	S. M. Radicella
Australia	K. D. Cole
Belgium	P. C. Simon
Brazil	B. R. Clemesha
Czechoslovakia	J. Lastovicka
Denmark	J. K. Olesen
Finland	C. Sucksdorff
France	M. L. Chanin
FRG	U. von Zahn
GDR	J. Taubenheim
Hungary	P. Bencze
India	Y. V. Somayajulu
Ireland	P. Lynch
Israel	J. Joseph
Italy	G.Fiocco
Japan	S. Kato
New Zealand	G. Fraser
Norway	E. Thrane
South Africa	G. J. Kuhn
Spain	J. O. Cardus
Sri Lanka	P. A. J. Ratnasiri
Sweden	G. Witt
Taiwan	J. K. Chao
United Kingdom	L. Thomas
United States	J. D. Mahlman
USSR	E. S. Kazimirovsky

PRE-MAP PROJECTS

PMP-1 Coordinated Study of the Behavior of the Middle Atmosphere in Winter, K. Labitzke, Chairman
PMP-2 Equatorial Wave Dynamics, I. Hirota, Chairman
PMP-3 Study of Photochemical Processes in the Upper Stratosphere and Mesosphere by Complementary Spacecraft, in situ, and Ground Measurements, J. C. Gille, Chairman
PMP-4 Presentation of Meteorological and Chemical Variables in the Format of Monthly Mean Zonal Cross Sections, J. Barnett, Chairman
PMP-5 Solar Spectral Irradiance Measurements, P. C. Simon, Chairman

MAP STUDY GROUPS

MSG-1 Tropospheric-Stratospheric Coupling, Chemical and Dynamical, J. R.Holton, Chairman
MSG-2 Transport of Trace Constituents, J. D. Mahlman, Chairman
MSG-3 Tides, Gravity Waves and Turbulence, M. A. Geller, Chairman
MSG-4 Electrodynamics of the Middle Atmosphere, H. Volland, Chairman
MSG-5 Ions and Aerosols, F. Arnold and M. P. McCormick, Co-Chairmen
MSG-6 Scientific Aspects of an International Equatorial Observatory, S. Kato, Chairman
MSG-7 Penetration of Solar Radiation into the Atmosphere, J. E. Frederick, Chairman
MSG-8 Atmospheric Chemistry, G. Witt, Chairman
MSG-9 Measurement of Middle Atmosphere Parameters by Long Duration Balloon Flights, J. E. Blamont, Chairman

MAP PROJECTS

AMA, Antarctic Middle Atmosphere Program, T. Hirasawa, Coordinator
ATMAP, Atmospheric Tides, Middle Atmosphere Program, J. M. Forbes, Coordinator
CAMP, Cold Arctic Mesopause Project, G. Witt, Coordinator
CLIMAT, Climatology of the Middle Atmosphere, J. M. Russell, III, Coordinator
DYNAMICS, Dynamics of the Middle Atmosphere in Winter, K. Labitzke, Coordinator
GLOBMET, Global Meteor Observation System, R. G. Roper, Coordinator
GLOBUS, Global Budget of Stratospheric Trace Constituents, J. P. Pommereau
GOSSA, Global Observations and Studies of Stratospheric Aerosols, M. P. McCormick, Coordinator
GRATMAP, Gravity Waves and Turbulence in the Middle Atmosphere Program, D. C. Fritts, Coordinator
MAC-Epsilon, E. V. Thrane, Coordinator
MASH, Middle Atmosphere Southern Hemisphere, A. O'Neill, Coordinator
MAC-SINE, Summer in Northern Europe, E. V. Thrane, Coordinator
MAE, Middle Atmosphere Electrodynamics, R. A. Goldberg, Coordinator
MSTRAC, MST Radar Coordination, P. K. Rastogi, Coordinator
NIEO, New International Equatorial Observatory, S. Kato, Coordinator
OZMAP, Observation of and Sources of the Spatial and Temporal Variability of Ozone in the Middle Atmosphere on Climatological Time Scales, D. F. Heath, Coordinator
SSIM, Solar Spectral Irradiance Measurements, P. C. Simon, Coordinator
SUPER-CAMP, E. Kopp, Coordinator
WINE, Winter in Northern Europe, U. von Zahn, Coordinator

MEETINGS OF MAP STEERING COMMITTEE

May 1978	Innsbruck, Austria
March 1979	Geneva, Switzerland
December 1979	Canberra, Australia
July/August 1980	Urbana, Illinois
May 1981	Hampton, Virginia
August 1981	Edinburgh, UK
May 1982	Ottawa, Canada
May 1983	Urbana,Illinois
November 1984	Kyoto, Japan
August 1985	Prague, Czechoslovakia
June 1986	Toulouse, France
August 1987	Vancouver, Canada
July 1988	Espoo, Finland
August 1989	Reading, UK

MAP ASSEMBLIES

August 1981	Edinburgh, UK
November 1984	Kyoto, Japan

MAP SYMPOSIA

December 1979, The Middle Atmosphere, Canberra, Australia
July/August 1980, Middle Atmosphere Dynamics and Transport, Urbana, Illinois
August 1981, Middle Atmosphere Sciences Symposium, Edinburgh, UK, and Hamburg, FRG
May 1983, Symposium on Ground-Based Studies of the Middle Atmosphere, Schwerin, GDR
August 1983, Interim Results from the Middle Atmosphere Program, Hamburg, FRG
June 1984, COSPAR Symposium on First Results of the Middle Atmosphere Program, Graz, Austria
September 1984, CLIMAT Symposium, Greece
November 1984, MAP Symposium, Kyoto, Japan
August 1985, MAP Symposium, Prague, Czechoslovakia
August 1985, GLOBMET Symposium, Dushanbe, USSR
July 1988, GLOBMET Symposium, USSR
July 1988, MAC Symposium, Espoo, Finland
April 1989, Solar Activity Forcing of the Middle Atmosphere, Liblice, Czechoslovakia
July/August 1989, IAMAP/IAGA MAP Symposium, Reading, UK
November 1989, Middle Atmosphere Studies, Dushanbe, USSR

MAP WORKSHOPS

May 1982, Workshop on Equatorial Middle Atmosphere Measurements and Middle Atmosphere Radars, Estes Park, Colorado
May 1982, Workshop on Comparison of Data and Derived Dynamical Quantities during Northern Hemisphere Winters, Boulder, Colorado
May 1982, Workshop on the Intercomparison of Solar UV Irradiance Measurements and Related Instrument Calibrations, Washington, DC
April 1983, Workshop on Comparison of Data and Derived Dynamical Qunatities during Northern Winters (1978-1982), Oxford, UK
May 1983, Workshop on the Technical Aspects of MST Radars, Urbana, Illinois
August 1983, Workshop on Tides in the Mesosphere and Lower Thermosphere, Hamburg, FRG
January 1984, GLOBUS Workshop, Munich, FRG
May 1984, Second Workshop on the Technical Aspects of MST Radars, Urbana, Illinois
December 1984, ATMAP Workshop, Kyoto, Japan
December 1984, GRATMAP Workshop, Kyoto, Japan
January 1985, GLOBUS Workshop, Paris, France
August 1985, Tides Workshop, Prague, Czechoslovakia
August 1985, OZMAP Workshop, Salzburg, Austria
October 1985, Third Workshop on the Technical and Scientific Aspects of MST Radar, Aguadilla, Puerto Rico
March 1986, Workshop on the Development of MST Radar Techniques during MAP and in the Future, Kyoto, Japan
April 1986, MASH Workshop, Williamsburg, Virginia
July 1986, Presentation of CIRA 1986 and Comparisons with other Models, Data and Theories, Toulouse, France
May 1987, GRATMAP Workshop, Adelaide, Australia
May 1987, MASH Workshop, Adelaide, Australia
October 1988, MAC-EPSILON/MAC-SINE Workshop, West Dennis, Massachusetts
November/December 1988, Fourth Workshop on the Technical and Scientific Aspects of MST Radar, Kyoto, Japan
December 1988, MAC-EPSILON/MAC-SINE, San Francisco, California
April 1989, MASH Workshop, San Francisco, California
April 1989, MAC-EPSILON/MAC-SINE Workshop, Lahnstein, FRG

DRAFT
MINUTES OF MAP STEERING COMMITTEE
Reading, UK, August 1, 1989

1. Welcome and Introductory Remarks

Chairman Bowhill welcomed everyone and announced that this was the final meeting of the MAP Steering Committee. He gave a brief history of MAP: the planning started in 1976, MAP itself was from 1981-85, MAC 1986-1988, MAS 1989-1990. Twenty-seven volumes of the MAP Handbook documented MAP activities and scientific achievements reported at symposia and workshops.

The participants introduced themselves. Dr. Geller led the discussion for transition into STEP.

2. Approval of Agenda

The Agenda was approved.

3. Minutes of 1988 Meeting

The Minutes of the 1988 Meeting in Espoo were approved with the correction to the AMA report which was given by M. D. Yamanaka (not M. Yamamoto).

4. Committee Reports

Data Management - Dr. Hirota reported limited responses to requests for inputs to a MAP Catalogue. Only USSR, Finland, Czechoslovakia, France and Japan responded with a total number of 60 subjects. Dr. Bowhill asked if the Japanese Data Book had been received by everyone. The Secretariat will send requests again to every country for data and letter of interest with replies due by October 31.

Publications - A list of the remaining MAP Handbooks to be published is given in Appendix 1. It was decided that MAP Data Management information should be given in the final planned volume No. 32. Concerning MAP Handbook Volume 32, the draft of the volume, circulated earlier to the Steering Committee, was discussed. It was noticed that the format of Recommendations in Chapter 6 was different from the other chapters. This will be corrected. Dr. Bowhill will prepare Chapter 1 and emphasize the difference of the contents in the MAP Planning Document and Volume 32.

5. Project Reports

ATMAP - The report is given in Appendix 2.
NIEO - Dr. Kato gave the report and it is given in Appendix 3.
MAE - Dr. Goldberg's report is contained in Appendix 4.
MASH - Dr. O'Neill reported.
GLOBMET - Dr. Roper gave the report.
CLIMAT - Dr. Russell referred to MAP Handbook Vol. 22 as the final report.
GRATMAP - Dr. Fritts commented that no formal activities have been going on since the Helsinki meeting.
Thrane reported on the DYANA project.

6. Workshops/Symposia

The following workshops/symposia have been/will be held since the last MAPSC meeting:
MST Radar Workshop, Kyoto, November-December 1988
MASH Workshop, April 1989 (Appendix 5)
MAC-Epsilon/MAC-SINE Workshop, April 1989
Solar Activity Forcing of the Middle Atmosphere, Czechoslovakia, April 1989 (Appendix 6)
IAMAP/IAGA MAP Symposium, July/August 1989

7. Evolving into STEP

Dr. Geller reported on behalf of Working Group 4 of STEP. He said suggestions for projects should concentrate on coupling mechanisms and phenomena that can be accomplished in the STEP period. Dr. Manson commented on the relation between STEP Working Groups 4 and 3. MLT network will be active in both LTCS and the Dynamics area of WG 4.

Dr. Chanin reported on the IGBP meeting held on July 30. Two issues were discussed: the ozone issue and solar UV flux have to be in IGBP. IGBP is slow in getting started; STEP is already working, but it is limited in duration. The project The Middle Atmospehre Response to Changes (MARC) will be proposed to IGBP by March 31, 1990. Once it is adopted, IAGA and IAMAP Chairmen will ask SCOSTEP to handle MARC. Dr. Bowhill stated that Joe Allen's viewgraph on the March 13 flare should be included in the report to IGBP.

Dr. Bowhill asked if other MAP projects should be included in STEP and commented that the transition would be successful.

8. Reports of Representatives of Countries

Reports were given as follows: USSR (Kazimirovsky); DDR (Taubenheim); Australia (Vincent); New Zealand (Keys)(Appendix 7); Japan (Kato); France (Chanin); Norway (Thrane); Canada (Manson)(Appendix 8); UK (Thomas); FRG (Labitzke); Italy (Fiocco); Sweden (Witt); USA (Geller). The report for Hungary (Bencze) is given in Appendix 9 The Secretary will write to National Representatives to ask for final MAP reports.

9. Other Business

Dr. Roederer, SCOSTEP President, congratulated the MAP Chairman and Steering Committee on having done a super job conducting the Middle Atmosphere Program and remarked that the results will be appreciated.

Co-Chairman Labitzke also expressed thanks and appreciation to the Chairman for his work with MAP.

A resolution from WG 2D of IAGA to transmit to the STEP Steering Committee will be provided by Dr. Simon.

The Agenda and list of Attendees is given in Appendix 10.

APPENDIX 1

MAP PUBLICATIONS

Tentative schedule for remaining MAP Handbooks

Vol. 28: Fourth MST Radar Workshop, Abstracts, November/December 1988, Kyoto
(in press)

Vol. 29: Part 1. Solar Activity Forcing of the Middle Atmosphere, Symposium held April 1989, Czechoslovakia, *Lastovicka*, editor
Part 2. Comparison of Satellite-Derived Dynamical Quantities in the Stratosphere of the Southern Hemisphere, MASH Workshop, April 1986, Williamsburg, VA, *Miles and O'Neill*, editors
(in press)

Vol. 30: International School on Atmospheric Radars, Lecture Notes, November 1988, Kyoto
Fukao, editor
(material in hand)

Vol. 31: *Part 1: 1988 GLOBMET Symposium, USSR, *Roper*, editor
Part 2: Middle Atmosphere Reference Models of Minor Species for COSPAR International Reference Atmosphere, *Keating*, editor
(material available in Fall)

Vol. 32: Part 1: MAP Summary, *Vincent,* editor
Part 2: Minutes of Final MAPSC Meeting
**Part 3: Data Management Information
**Part 4: Final Reports from Representatives of Countries

*Secretary's Note: Subsequently it was decided that the papers from this Symposium would not be published in the MAP Handbook series.
**It was decided at the meeting that Parts 3 and 4 would be included in the final volume.

APPENDIX 2

ATMAP Report to MAP Steering Committee

August 1, 1989

J. M. Forbes

A Special Issue of JATP on the ATMAP will appear during 1989. ATMAP is ended. There is no ATMAC. We are now moving on to LTCS, a project that focuses on the <u>coupling</u> between the mesosphere and the thermosphere. LTCS is part of CEDAR and WITS.

APPENDIX 3

Report on NIEO

Susumu Kato

There have been the following activities relative to NIEO since last year.

1. Visit to Shigaraki MU Observatory by Minister of Research and Technology of the Republic of Indonesia, Prof. Dr. Habibie, November 1988.

Mr. Habibie visited Shigaraki and seemed much impressed by the MU radar, staying with us for three hours. On this occasion he mentioned his strong interests in the importance of the Indonesian Archipelago which influences global atmosphere environment through intense ocean-atmosphere interactions in that region. We discussed NIEO to play a role in understanding of detail atmospheric behavior of the region thereby contributing to the elucidation of global environmental problems.

2. Seminar in Jakarta, March 1989, on Indonesia and Global Weather

The seminar was organized by BPPT (Agency for the Assessment and Application of Technology) co-sponsored by Japan-Indonesian Science and Technology Forum, and NOAA, and attended by 30 ~ 100 people. Profs. Kato, Fukao (Kyoto University) and Sumi (University of Tokyo) and two government officials (Agency of Science and Technology, Agency of Environment) from Japan and Prof. Webster (Pennsylvania University) Mr. Hall (NOAA) and two other scientists from the USA participated in the seminar. Besides scientific discussion relative to ocean-atmosphere interactions, El Nino, tele-connection etc., it was informed that the Indonesian Government is willing to cooperated in scientific observation of the region relative to the earth's environment as that by ships of other countries to work in Indonesian territorial water. Mr. Habibie agreed and promised to promote the NIEO project on his side. He suggested us extensive survey on possible sites of equatorial radar to obtain the most feasible one.

3. Science grant of Ministry of Education, Science and Culture of Japan for feasibilty study of NIEO.

We have obtained a Science Grant of Ministry of Education, Science and Culture in the 1989 FY for doing a feasibility study of NIEO. A group of scientists headed by Prof. Kato visited Indonesia, Sumatra, Kalimantan and Celebes for that purpose in June-July and September-October 1989.

Although the NIEO project has been formally submitted from Kyoto University to the Ministry of Education, Science and Culture of Japan for funding, there are, besides the construction funding, various problems as to the organization responsible for operating NIEO, the way of international cooperation in the operation, etc.

APPENDIX 4

MAP Project Report: Middle Atmospheric Electrodynamics (MAE)

R. A. Goldberg

To my knowledge, no new rocket experiments have been conducted to continue research in this field since my report submitted at the last MAPSC meeting and which appears in Handbook for MAP, Volume 27, although several projects are in the planning stage. MAC/REP is planned as a rocket series at Poker Flat, Alaska, during autumn 1989, and will be used to study the impact of highly relativistic electron showers (>1 MeV) on middle atmospheric electrodynamical behavior and chemistry. DYANA is a European program planned for 1990 to study global dynamics and electrodynamics in the middle atmosphere. DECIMALS is a Swedish/Swiss joint effort to study the neutral and charged particle environment in the vicinity of noctilucent clouds (NLCs) planned for the NLC viewing season in the summer of 1991. Several groups have now joined forces to propose a NSAS rocket program for study of the relationship between NLCs and polar mesospheric summer echoes (MPSEs) seen near the mesopause by EISCAT and MST radars. Should NLC-91 be approved, it would combine in a joint program with DECIMALS. There is also renewed activity in this research area within the USSR where new rocket flights are studying middle atmospheric electric fields using the field mill technique.

MAC/Epsilon, conducted from Andoya, Norway, in October and November 1987, is the most extensive recent rocket program dealing with MAE. Several papers have already been presented at meetings such as the ESA Symposium on Rockets and Balloons, Lahnsten, FRG, April 1989; the American Geophysical Union (AGU) Meeting in San Francisco, CA, USA in December 1988, etc. In addition, a special issue of the Journal of Atmospheric and Terrestrial Physics will be dedicated to results from the MAC/Epsilon and MAC/SINE programs.

The Committee for Atmospheric and Space Electricity (CASE) of AGU has also been sponsoring sessions relating to MAE and have coordinated with the atmospheric electricity community to locate subjects of common interest to both groups. Such attempts at uniting different disciplines with common interests should have a very positive affect on progress within the related fields. The IAGA Working Group IIA on middle atmospheric electrodynamics has been pursuing similar goals. It is our hope that STEP will continue to find a home for this discipline, and such a program has been proposed to Working Group 4 of that organization.

Finally, a MAP volume surveying the first decade during MAP is expected to be released in the very near future. One chapter will deal with MAE, including a listing of proposed activities for future emphasis.

APPENDIX 5

REPORT ON MASH WORKSHOP, APRIL 1989

A. O'Neill

The third MASH Workshop was organized as a NATO Advanced Research on Dynamics, Chemistry and Photochemistry in the Middle Atmosphere of the Southern Hemisphere. It was held in San Francisco, CA, 15-17 April 1989, and was cosponsored by the North Atlantic Treaty Organization (NATO), the University of California at Los Angeles (UCLA), and the National Aeronautics and Space Administration (NASA). The American Meteorological Society was a cooperating organization. The Workshop directors were Dr. A. O'Neill (Meteorological Office, UK) and Professor C. R. Mechoso (UCLA).

The Workshop was organized into five sessions with oral presentations, and one session with a general discussion. About 50 scientists attended the sessions and actively participated in the exchange of ideas that followed each one of the 30 oral presentations, as well as in the general discussion.

Session 1 began with a review paper (Dr. M. E. McIntyre) on current challenges to our understanding of the middle atmosphere, and was followed by papers on the seasonal evolution of the extra-tropical middle atmosphere (Dr. A. O'Neill), photochemistry of the Antarctic stratosphere (Dr. S. Solomon), and observational aspects of gravity waves in the Southern Hemisphere (Dr. R. A. Vincent).

In session 2, theoretical aspects of gravity waves (Prof. D. C. Fritts) and observations and theories of traveling waves in the middle atmosphere (Prof. I. Hirota) were considered. The important topic of data sources and quality for the troposphere and stratosphere of the Southern Hemisphere was discussed (Dr. D. Karoly), and a study of coherent wave-mean flow interactions in the troposphere of the Southern Hemisphere was presented (Dr. W. J. Randell).

Dynamics and transport were the main themes of session 3. An account of the evolution of final warmings in the middle atmosphere of the Southern Hemisphere (Prof. C. R. Mechoso) was followed by a paper on the climatology of the spring Austral stratosphere (P. Newman). The so-called dilution effect in connection with the break-up of the Antarctic ozone hole was considered (Prof. R. A. Plumb), and data collected during the Airborne Antarctic Ozone Experiment in 1987 were used to place constraints upon the effect of transport on ozone mixing ratios in the south polar vortex during spring 1987 (Prof. D. L. Hartmann).

Session 4 dealt with the potential role of HO_x and ClO_x interactions in ozone-hole photochemistry (Prof. P. J. Crutzen), and with the role of aerosols and clouds in stratospheric photochemistry (Prof. R. P. Turco). These papers were followed by a study, based on a three-dimensional model, of transport processes in t he middle atmosphere of the Southern Hemisphere (Dr. W. L. Grose). The session closed with an overview of future observations of the middle atmosphere (Dr. J. C. Gille).

The last formal session of the Workshop, session 5, began with a paper describing an experiment in which a three-dimensional model was used to study the dynamical effects of the Antarctic ozone hole (Dr. J. D. Mahlman). The modeling theme continued with a paper on circulation and transport in polar regions in spring, as diagnosed in a two-dimensional model of coupled dynamics, radiative transfer and chemistry (Prof. K. K. Tung). A paper on the use of diagnostics in modeling and observational studies (Dr. D. G. Andrews) closed the session.

Drs. W. L. Grose, J. D. Mahlman and Prof. R. P. Turco led a lively panel discussion on outstanding issues. Areas that were identified for further research included (1) the physical chemistry and microphysics of polar stratospheric clouds, (2) the possible implications for global ozone of heterogeneous chemistry on sulphate aerosols, (3) the coupling of chemistry, radiation and dynamics in the middle atmosphere, (4) sources of traveling planetary waves in the stratosphere of the Southern Hemisphere during spring, (5) sources of wave activity in the troposphere of the Southern Hemisphere that could influence the stratospheric flow, and (6) reasons for the amplification of zonal wavenumber 1 in the stratosphere during the spring final warming.

Proceedings of the Workshop will be published (probably early in 1990) by Kluwer Academic Publishers as a volume in the NATO Advanced Research Workshop series. The volume will be edited by Dr. A. O'Neill and Prof. C. R. Mechoso.

APPENDIX 6

Report on IAGA Symposium Solar Activity Forcing of the Middle Atmosphere

J. Lastovicka

The Symposium held on 3-8 April 1989 in the Castle of Liblice, Czechoslovakia, was organized by the IAGA Working Group II.D "External Forcing of the Middle Atmosphere " (cochairmen J. Lastovicka and R. F. Donnelly) and by the Geophysical Institute of the Czechoslovak Academy of Sciences (Director Prof. V. Bucha, past Vice President of IAGA), and co-organized by the ICMUA/IAMAP Working Group on Solar-Terrestrial Relations, r. F. Donnelly, J. Lastovicka (convenors), A. Ebel (ICMUA/IAMAP) and J. Taubenheim (IAGA) were members of the Program Committee. the Organizing Committee was chaired by J. Lastovicka. The Symposium was sponsored by IAGA and cosponsored by the MAP Steering Committee and by ICMUA/IAMAP.

Eighty scientists from 12 countries and 4 accompanying persons took part in the Symposium. All facilities, including accommodation and board, were provided at the Castle. The living expenses of 10 participants were covered by the Organizing Committee (2.5 from the IAGA financial support, 7.5 from Czechoslovak funds). Travel expenses of 3 participants from China and India were covered by IUGG.

The Symposium consisted of 8 blocks: 1. Related Papers, 2. Influence of Quasi-Biennial Oscillation, 3. Influence of Solar Electromagnetic Radiation Variability, 4. Solar Wind and High Energy Particle Influence, 5. Circulation, 6. Atmospheric Electricity, 7. Lower Ionosphere, 8. "Solar" Posters. Nineteen invited, 26 contributed and 7 poster papers were presented. They will be published in HANDBOOK FOR MAP, Volume 29, September 1989.

APPENDIX 7

MAP ACTIVITIES IN NEW ZEALAND

G. J. Fraser

I. PHYSICAL AND ENGINNERRING LABORATORY, LAUDER

A. Stratospheric Trace Gas Studies:

1. Study of twilight stratospheric NO_2 and O_3 using differential absorption spectroscopy at Lauder (45.0°S, 169.7°E). The technique involves grating spectrometer scans of scattered sunlight in the zenith. Day-to-day and seasonal variability of stratospheric NO_2 are being analyzed in terms of the interwoven effects of chemistry and transport, and the results are being examined in conjunction with ground-based and satellite meteorological data. Measurements were also made on a campaign basis from Aire sur l'Adour, France (0.3°E, 44°N), during September/October 1985, as part of MAP GLOBUS 85, from Kiruna, Sweden (21°E,68°N) in January/February 1989, and from the Jungfraujoch Observatory (8°E,47°N) during March/April 1989.

Ozone: From August 1986, regular weekly (and in spring and early summer twice weekly) ozone sonde flights have been made from Lauder with an average burst height of 31 km. From January 1987, an automated Dobson spectrophotometer was installed at Lauder and was well as manual direct sun total observations this instrument records Umkehr values automatically. It is on e of the seven instruments that constitute the "Automated Dobson Network".

2. Comparison of NO_2, O_3 data from ground-based experiments as above with SAGE satellite data (in conjunction with NASA).

3. Direct sun measurements of HNO_3, Hcl and other species using Michelson Fourier Transform spectroscopy (in cooperation with University of Denver) in the 3 μ and 7 - 14 μ windows have been performed for approximately 6 weeks/year from 1985 to present.

B. Tropospheric Trace Gas Studies:

Analysis of the sources, sinks and variability of certain species which are of importance in the stratospheric studies:

1. Long path measurements of NO_2 using the DAS technique with grating spectrographs and viewing distant light sources. Problems such as the rejection of atmospheric flicker have been overcome to give measurements with a detection threshold for NO_2 approaching 15 ppt.

2. In site-sampling of O_3 (in cooperation with New Zealand Meteorological Service) and NO/NO_x using chemiluminescent techniques (with University of Nagoya).

C. UV Radiation Studies:

1. Measure the absolute spectral irradiance of solar UV (direct and scattered) received at the surface in New Zealand. Units: Wm^{-2} nm^{-1}; Range: 290-450 nm; Resolution: 1 nm.

2. Quantify temporal and geographic variabilities, and identify causes for any differences (e.g., in terms of atmospheric composition).

3. Monitor the integrated erythermal UV flux using an instrument incorporating a filter that mimics the human erythermal response.

4. Apply radiative transfer calculations to intercompare these measurements and assess our understanding, and hence our ability to predict the effects of changes in atmospheric composition.

D. Antarctic Stratospheric Trace Gas Studies:

1. Study of stratosphere slant column NO_2 and O_3 using differential absorption spectroscopy as in (A1) above at Arrival Heights (78°S,167°E), Halley Bay (76°S,27°W) in

conjunction with British Antarctic Survey), and South Pole Station (in conjunction with GMCC, NOAA).

2. Spring studies column HNO_3 and HCl at Arrival Heights (in conjunction with the University of Denver).

3. Autumn studies of column HNO_3 at Arrival Heights (in conjunction with the University of Denver).

II. NEW ZEALAND METEOROLOGICAL SERVICE, WELLINGTON

Ozone measurements (project scientist: Sylvia Nichol): Routine measurements of total column ozone are made at Arrival Heights, near Scott Base (78°S,167°E) using both a Dobson spectrophotometer (since January 1988) and a Brewer instrument (since February 1989). The Brewer is being run as a cooperative project with the Italian Antarctic program. Umkehr measurements are made in autumn and spring whenever conditions allow. Interpretation of ozone amounts is being made with emphasis on the correlations with lower stratospheric temperatures. The New Zealand Meteorological Service Dobson instrument was operated at Invercargill for a long period up to September 1987. Work continues on evaluating this record.

III. UNIVERSITY OF CANTERBURY, PHYSICS DEPARTMENT, CHRISTCHURCH

A. The Antarctic Mesosphere:

Electron density measurements (project scientist: Andre von Biel) are made at Scott Base (78°S,167°E) with the 2.4 MHz D-region polarimeter observations of the differential absorption between ordinary and extraordinary components of the partially reflected waves. There is evidence from the results obtained of the occasional existence of a thin layer of ionization which has a maximum of electron density at about 50 km. The probability of observing this phenomenon maximizes at local magnetic midnight (approximately 0730 UT), and during the Austral summer months.

Spaced antenna mode wind measurements (project scientist: Grahame Fraser) are also made with the Scott Base 2.4 MHz radar. The Polar Mesosphere Summer Echo has also been observed, in the form of decreased lifetime (after correction for advection by the wind) of electron density irregularities above the summer mesopause. There is a strong semidiurnal component in the variation of lifetime which results in a minimum lifetime with a maximum westward phase of the semidiurnal tide. The wind observations have also contributed to cooperative global observation programs such as the Atmospheric Tides in the Middle Atmosphere Program, the Global Thermospheric Mapping Study, and the Lower Thermosphere Coupling Study. Preliminary measurements of scattering processes using frequency domain interferometry were carried out over the 1988/9 season.

B. The Midlatitude Mesosphere:

Spaced antenna wind measurements (project scientist: Grahame Fraser) are also made at Christchurch (44°S,173°E). These observations have also contributed to the cooperative global programs. A study is currently in progress on the comparison of mesospheric planetary waves with stratospheric waves derived from satellite radiance measurements.

C. Ozone and Aeorsol Measurements:

Preliminary measurements have been made in NZ and Antarctica with a multiwavelength interference filter direct-sun photometer to assess total column ozone and aerosol content. Observations included the recovery of ozone content at Scott Base (78°S,167°E) in November 1986.

APPENDIX 8

MAP ACTIVITIES - CANADA

A. H. Manson

There is growing interest in middle atmosphere research in Canada. In particular, two Ontario universities (Western Ontario/York) have additional research professors, and optical (lidar, Michelson) and radar (MF) systems are planned. The MF radars (Saskatoon and Tromso) of the University of Saskatchewan continue to be very active in WITS/CEDAR.

The Canadian Space Science community also continues to be very active with WAMDII (Space Shuttle) and WINDII (UARS) instruments (Gordon Shepherd, York, P.I.) for wind measurements in the mesosphere and lower thermosphere.

The Government laboratory group most involved in the middle atmosphere is the Atmospheric Environment Service, which is our "Meteorological Service". There are ozone and minor constitutent studies and very significant COCM work.

APPENDIX 9

MAP ACTIVITIES - HUNGARY 1988/89

P. Bencze

1. Changes of solar and meteorological origin in the mesosphere and lower thermosphere

The study of the effect of solar-terrestrial events in the middle atmosphere has been continued in the Geodetic and Geophysical Research Institute, Sopron, Hungarian Academy of Sciences. By investigating the distribution of electron density in the lower ionosphere, it has been found that connected with Forbush decreases and subsequent particle precipitation a local minimum occurs in the electron density profile at about 70 - 72 km. In consequence of this the geomagnetic storm aftereffect in the ionospheric absorption of LF radio waves is modified appearing at the low frequency end of the range, but decreasing with increasing frequency.

A study of the effect of interplanetary phenomena on the ionospheric absorption of radio waves indicates that shock related magnetic clouds are more efficient in producing storm aftereffect. In this respect the plasma parameters of magnetic clouds have also been studied.

2. Turbulence

The method developed for the determination of turbulent parameters in the lower thermosphere based on sporadic E parameters in the Geodetic and Geophysical Research Institute, Sopron, Hungarian Academy of Sciences has been used for the determination of the vertical shear of the horizontal wind. Assuming saturation of the gravity waves producing the wind shear, the vertical wavelength of these waves can be determined. In the lower thermosphere the diurnal variation of the vertical wavelength indicates a maximum in the midday hours, while the seasonal variation shows a maximum in the winter months. The vertical wavelength seems to decrease with increasing mean wind speed.

APPENDIX 10

MAP STEERING COMMITTEE MEETING

August 1, 1989, 6:00 PM

Whiteknights Hall Library, University of Reading
Reading, UK

AGENDA

1. Welcome and Introductory Remarks
2. Approval of Agenda
3. Minutes of 1988 Meeting
   Correction: AMA: M. D. Yamanaka reported (not M. Yamamoto)
4. Committee Reports
   Data Management
   Publications
5. Study Groups and Projects Reports
6. Workshops/Symposia
   MST Radar Workshop, Kyoto, November-December 1988
   MASH Workshop, San Francisco, April 1989
   MAC-Epsilon/MAC/SINE Workshop, Lahstein, Germany, April 1989
   Solar Activity Forcing of the Middle Atmosphere, Czechoslovakia, April 1989
   IAMAP/IAGA MAP Symposium, July/August 1989
   MAC Symposium, Dushanbe, USSR, November 1989
   MST Radar Workshop, Aberystwyth, UK, August 21-24, 1990
7. Evolving into STEP
   MARC Program
8. Report from Representatives of the Countries
9. Other Business

Attendees MAP Steering Committee Meeting

Ahluwalia, H. S.
Avaste, O.
Bonetti, A.
Bowhill, S. A.
Chanin, M.-L.
Fiocco, G.
Fritts, D.
Geller, M. A.
Gille, J.
Goldberg, R.
Hirota, I.
Holopainen, E.
Kato, S.
Kazimirovsky, E.
Keys, G.
Kopp, E.
Labitzke, K.
Liu, C. H.
Manson, A. H.
O. Neill, A.
Roederer, J. G.
Roper, R. G.
Russell, J.
Simon, P. C.
Taubenheim, J.
Thomas, L.
Thrane, E.
Vincent, R. A.
G. Witt

MAP ACTIVITIES IN AUSTRALIA

Organization

The Australian Middle Atmosphere Program was coordinated by a subcommittee of the National Committee for Solar-Terrestrial Physics. The chief tasks of the subcommittee were:

1. Stimulating MAP interest amongst Australian scientists in the early 1980s,
2. Reporting to the national STP Committee,
3. Setting up MAP Workshops at regular national meetings of the Australian Institute of Physics.

Australian Institutions Involved with MAP

MAP activities were undertaken by individuals and groups at the following institutions:
University of Adelaide
University of New South Wales
University of Queensland
Monash University
CSIRO, Division of Atmospheric Research.

MAP Personnel

Dr. R. A. Vincent of the University of Adelaide was appointed to the MAP Steering Committee in 1984.

Scientific Activities

1. Dynamical Studies

A major study of the dynamics of the atmosphere between 80 and 100 km was undertaken at the University of Adelaide Research Station at Buckland Park using ground-based radio methods. Regular observations extending over most of the MAP/MAC period have given detailed information on the mean winds, planetary waves, tidal winds, gravity waves and turbulence. The development of radar techniques for measuring momentum transport by gravity waves, and the measurement of turbulence parameters in this region have been two highlights of this work.

Starting in July 1984, the dynamics of the 70 - 110 km region at Mawson in the Antarctic were studied on a continuous basis as part of a program run jointly by the Upper Atmosphere Group and the Mawson Institute for Antarctic Research at the University of Adelaide.

During the latter part of MAP/MAC a study of the dynamics and structure of the D region was carried out by the Ionospheric Group of the University of Queensland.

A determination of lunar tides in the 80 - 100 km region using wind data recorded during MAP, was carried out by R. J. Stening of the University of New South Wales.

During most of the MAP/MAC period B. G. Hunt of the Division of Atmospheric Research, CSIRO, continued the development of a general circulation model that extended from the surface to 100 km. The model includes the effect of land-sea contrast, breaking gravity waves, and solar diurnal variability.

Theoretical studies of the Southern Hemisphere stratospheric circulation were undertaken by D. J. Karoly of Monash University, and by R. A. Plumb of the Division of Atmospheric Research, CSIRO.

2. Temperature Measurements

Measurements of temperatures near 90 km were carried out at Adelaide and Mawson (Antarctica) using ground-based optical methods developed at the Mawson Institute of Antarctic Research at the University of Adelaide.

Solar Terrestrial Energy Program

The majority of the programs described above are continuing as part of STEP.

Conferences and Workshops

The ongoing MAP activities were reported at Workshops held in conjunction with the national meetings of the Australian Institute of Physics.

The observational techniques used by the various Australian groups during MAP were discussed at the lst Australian Conference on the Physics of Remote Sensing of Atmosphere and Ocean held at Melbourne in February 1984.

The two most significant meetings were the international workshops on the Middle Atmosphere of the Southern Hemisphere (MASH), and Gravity Waves and Turbulence in the Middle Atmosphere Program (GRATMAP), held at Adelaide during May 1987. The papers presented at these workshops were published in Pure and Applied Geophysics, **130**, (2,3), 1989.

MAP ACTIVITIES IN BRAZIL: 1981 - 1989

The main centre for middle atmosphere research in Brazil is the Space Research Institute (I.N.P.E.), at São José dos Campos, in the state of São Paulo, although some work is also carried out at other research centres and universities. During the period covered by MAP work was carried out in the following areas: tropospheric and stratospheric ozone, tropospheric CO, stratospheric aerosols, atmospheric tides and gravity waves, minor constituents in the middle atmosphere and D-region ionization.

Tropospheric and stratospheric minor constituents.

Total ozone measurements were made at Cachoeira Paulista and Natal by Dobson spectrophotometers throughout the MAP period. Surface ozone was measured at Natal and Cuiabá. Stratospheric ozone profiles were measured regularly at Natal, using ECC sondes, and were also obtained in the Amazon rain forest during the 1987 GTE- ABLE experiment. The occurrence of significantly lower surface ozone concentrations in the Amazon region, as compared with Natal, a coastal site, has been attributed to increased loss of ozone by reactions with NO. Surface CO was measured regularly at São José dos Campos, Natal and Fortaleza. All these measurements are continuing in the post-MAP period.

Stratospheric Aerosols

The stratospheric aerosol scattering profile was measured by laser radar at São José dos Campos. Regular measurements were carried out throughout the MAP period, which included the eruption of the El Chichón volcano in Mexico, responsible for a major stratospheric injection. The decay rate for this injection was found not to differ significantly from that observed in the northern hemisphere, although the maximum aerosol burden was much less.

Mesospheric dynamics and temperature.

Studies of mesospheric dynamics have been carried out via lidar measurements of the vertical distribution of atmospheric sodium and via airglow observations. The airglow measurements of relevance to the middle atmosphere, made in Cachoeira Paulista and Fortaleza, included the OI 5577;A, OH (8,3), O_2 atmospheric band 8645;A and NaD 5890;A emissions. The O_2 and OH measurements are used to determine rotational temperature, and a long sequence of observations has made it possible to obtain mean annual variations for this parameter in the emission regions between 85 and 95 km. These variations have been found to be in much better agreement with CIRA 72 than with the more recent models. The sodium lidar profiles have been used to determine the principal diurnal and semidiurnal tidal components in the 80-110 km region and their seasonal variations at 23°S.

Rocket Sounding

A somewhat sporadic rocket sounding program was conducted during the MAP period, with two successful launches relevant to MAP. These experiments included photometers to measure the OI 5577 Å and O_2 7619 Å emissions simultaneously with electron density and electron temperature. Three experiments originally planned for 1988 were postponed till 1991 because of delays in the new launch site being built at Alcântara.

Atmospheric Electricity

In the field of atmospheric electricity, balloon measurements were made of electric fields and conductivity over electrified clouds and thunderstorms. These measurements were aimed at studying the charge distribution inside the clouds as well as their influence on the surrounding environment. This effort is now being extended by INPE's participation in the NASA/NSF ELBBO project, which will use long duration balloon flights to measure several atmospheric parameters at middle and high latitudes in the southern hemisphere.

Ionosphere

Studies of the ionized middle atmosphere were mainly concerned with the aeronomic effects of particle precipitation in the South Atlantic Anomaly. In this context, VLF oblique sounding has been used to study ionization and recombination effects in the D-region, and trans-polar VLF propagation measurements were used to investigate PCA events.

B. R. Clemesha
I.N.P.E., C.P. 515
12201, S. J. dos Campos
S.P., BRAZIL

CZECHOSLOVAK ACTIVITY IN MAP, 1981-1989

J. Laštovička

Geophysical Institute, Czechosl.Acad.Sci., Boční II, 141 31 Praha 4, Czechoslovakia

The Czechoslovak national MAP program consisted of 6 scientific subprograms:

1) "Disturbances of the Atmosphere at Heights of 120 to 40 km by Penetration of Meteoroids of Metre and Decimetre Dimensions":

Systematic photographic observations of fireballs were performed at many stations in Czechoslovakia, the FRG, the GDR and the Netherlands. They yielded multistation records of about 45-50 fireballs per year. Results of the most significant fireballs have regularly been published in the SEAN bulletin. Several fireballs penetrated the whole middle atmosphere, some of them down to the Earth's surface, and all were used to derive the instantaneous air-density profiles at heights 80-20 km.

2) "Meteor Radar Observations":

The variability of activity of meteor showers and of sporadic meteoric background was determined. Long-period joint observations of Perseide shower were analyzed to investigate the development of its activity and structure; a similar study was performed for 5 other meteor showers based on data from Ondřejov only. The mass distribution of meteoric particles and the structure of some meteor showers were studied, as well. The results have been regularly published in astronomical journals, particularly Bull. Astr. Inst. Czech.

The subprograms (1) and (2) belonged to the GLOBMET project.

3) "Winter Anomaly":

The MAP/WINE winter of 1983/84 was tudied in more detail. Ionospheric data were grouped not according to latitude or longitude, but according to height due to an opposite response to meridional wind at meteoric heights; none of the other parameters (geomagnetic and solar activity, stratospheric temperature, zonal wind) affect this grouping much. A similar division was not observed in the MAC/SINE summer of 1987. The difference between the response of the winter anomaly in Central and Southern Europe to strong stratospheric warmings was found to be caused by a different response of the stratosphere in Central and Southern Europe to strong stratospheric warmings. The ionospheric radio-wave absorption in Central Europe was depressed during stratwarm associated reversal of the lower thermospheric zonal wind in winters of 1986/87, 1987/88 and 1988/89, more after late winter warmings than after a very early winter warming.

4) "Aeronomic Studies with the Use of Ground-Based Measurements of Radio Wave Propagation":

A diurnal asymmetry was found in summer NO concentration in the mesoupause region. A relation was established between the radio wave absorption in the lower ionosphere and foF2 for summer 1969; the NO concetration estimated with the use of this relation was reasonable, $7 \times 10^{13}\ m^{-3}$ at 88-90 km. The periodicities observed in the day- and night-time LF radio wave absorption (2.3-3.2, 4-6 and 10.5-12 days in Central and Southern Europe, 7-9 days only in Central Europe) were proved to be of non-solar, very probably of meteorological origin. It was found their connection with the amplification of the quasi-stationary planetary waves in the stratosphere with a zonal wave number 2 during the winter periods of 1983/84 and 1984/85. An analysis of ionospheric data, particularly of radio wave absorption showed that the equatorward boundary of the auroral zone was shifted to geomagnetic latitudes below 50°N during and just after the extremely severe geomagnetic storm of February 1986.

5) "The Interplanetary Magnetic Field Effects in the Ionosphere and Atmosphere":

The IMF sector structure effects in various meteorological parameters above Berlin between 1000-10 hPa displayed the only persistent and statistically significant effect (even if rather weak) in the troposphere at 500 hPa. The effect of the IMF sector structure in total ozone in midlatitudinal Europe was found to exist for proton sector boundaries, but not for common sector boundaries; such an effect was not observed in the ozone mass mixing ratio in the upper stratosphere between 10-0.4 hPa and 40°-60°N in winter. A brief overview of the IMF sector boundary crossing effects in the middle atmosphere of middle latitudes was published by Laštovička (Adv. Space Res., 8_ (1988), No. 7, 201-204) - effects exist in the lower ionosphere and the troposphere, disappear in the lower stratosphere and their existence in the upper stratosphere and lower mesosphere is questionable.

6) "The Dynamics of Penetration of Convective Clouds into the Stratosphere":

Many data on penetration of cumulus and cumulonimbus clouds into the stratosphere were obtained. The algorithm of the dynamic recognition of development of convective cloudness was established with a particular emphasis on the penetration of cumulonimbus clouds into the stratosphere; another algorithm was elaborated for the selection and development of signatures to determine the classification of selected classes of clouds and phenomena. New methods based on correspondence of equal radiolocator reflectivity were elaborated for the determination of the development of convective cloudness including forecast up to 60 minutes.

MAP ACTIVITIIES WITH DANISH PARTICIPATION FROM 1981 THROUGH 1989.

Ib Steen Mikkelsen

Division of Geophysics, Danish Meteorological Institute

In the 1980s danish scientists have participated in several balloon campaigns to study the electrodynamics of the high-latitude stratosphere. This region is penetrated by electric fields and currents of tropospheric, in situ, and magnetospheric origin. D'ANGELO et al. (1982) observed that the fair-weather downward stratospheric current is also present in arctic latitudes and exhibits the same UT variation as observed at lower latitudes. For magnetically disturbed conditions they found that the fair-weather current on a statistical basis was increased(suppressed) by 15-20% underneath the dawn(dusk) extrema of the magnetospheric electrostatic potential. BARCUS et al. (1986a), based upon balloon-borne observations of the electric field and conductivity, estimated 0.5 A enhancements of the downward current integrated over an arctic storm system. Over the convection regions of the storm they observed 1-2 volt/m both upward and downward electric fields. Unusual electric field structures of magnitude 3-8 volt/m were also reported be MADSEN et al. (1983), but the origins of these have not been identified. D'ANGELO et al. (1983) suggested that low frequency (≤ 1 Hz) stratospheric electrostatic noise, present 1-3% of the time, was related to thin turbulent layers created by unstable gravity waves. Finally BARCUS et al. (1986b) in a solar particle event observed Bremsstrahlung due to solar electrons that arrived before the solar protons. They further demonstrated how the cut-off of this Bremsstrahlung expanded equatorward in connection with an equatorward shift of the socalled cusp region.

Absorption data from the high-latitude network of riometers operated by the Danish Meteorological Institute have been used in the Energy Budget Campaign (BREKKE et al. 1985, FRIEDRICH et al., 1985), in the MAP/WINE campaign (WILLIAMS et al. 1987), and by BARCUS et al. (1986b) to determine the extent of the hard particle precipitation.

In 1989 the Danish Meteorological Institute started an extensive program to study the arctic ozone layer. In collaboration with Service D'Aeronomie, France a spectrometer, called SAOZ, was installed in Søndre Strømfjord, Greenland, and the Dobson instrument was moved from Århus, Denmark to the same site. It is planned to observe ozone and the incoming UVB (280-320 nm) radiation in the next decade. More than 50 ozonesonde balloons were launched from Ammassalik and Scoresbysund at the Eastcoast of Greenland during the AASE campaign. A model study of the formation of polar stratospheric clouds (PSC) has been started. The cloud model will be built into the global chemical/dynamical stratosphere model at Oslo University, Norway.

References

Barcus, J. R., I. Iversen, and P. Stauning, Observations of the electric field in the stratosphere over an arctic storm system, **J. Geophys. Res.**, **91**, 9881-9892, 1986a.

Barcus, J. R., K. D. Hudnut, P. Stauning, I. B. Iversen, and J. Phillips, Observation of Bremstrahlung from solar electrons in the earth's atmosphere, **J. Atmos. Terr. Phys.**, **48**, 375-384, 1986b.

Brekke, A., O. Holt, P. H. G. Dickinson, M. Friedrich, T. Hansen, P. Stauning, and E. V. Thrane, Development of D-region electron and ion densities under various auroral conditions during the energy budget campaign (EBC), **J. Atmos. Terr. Phys.**, **47**, 101-121, 1985.

D'Angelo, N., I. B. Iversen, and M. M. Madsen, Influence of the dawn-dusk potential drop across the polar cap on the high-latitude atmospheric vertical current, **Geophys. Res. Lett.**, **9**, 773-776, 1982.

D'Angelo, N., I. B. Iversen, and M. M. Madsen, Low frequency (f ≤ 1 Hz) stratospheric noise measured by balloon-borne sensors, **J. Geophys. Res.**, **88**, 5441-5450, 1983.

Friedrich, M., K. D. Baker, P. H. G. Dickinson, A. Dumbs, B. Grandal, Ø. Andreassen, E. V. Thrane, L. G. Smith, P. Stauning, K. M. Torkar, Synopsis of the D- and E-regions during the energy budget campaign, **J. Atmos. Terr. Phys.**, **47**, 89-100, 1985.

Madsen, M. M., N. D'Angelo, and I. B. Iversen, Observations of unusual structures of high-latitude stratospheric electric fields, **J. Geophys. Res.**, **88**, 3894-3896, 1983.

Williams, E. R., G. W. Watkins, T. A. Blix, E. V. Thrane, G. Entzian, G. Von Cossart, K. M. Greisiger, W. Singer, J. Taubenheim, M. Friedrich, C. M. Hall, J. R. Katan, J. Lastovica, B. A. de la Moreno, S. V. Pakhomov, H. Ranta, Z. Ts. Rapoport, V. M. Sinelnikov, D. Samardjiev, G. Nestorov, H. H. Sauer, and P. Stauning, The ionosphere: Morphology, development, and coupling, **J. Atmos. Terr. Phys.**, **49**, 777-808, 1987.

MAP ACTIVITIES IN HUNGARY 1981-1989

P. Bencze

Geodetic and Geophysical Research Institute Hungarian Academy of Sciences, H-9401 Sopron, Box 5.

Hungary took part in MAP activities by measurements and by the investigation of phenomena related to the middle atmosphere. Six topics have been selected for studies during the MAP period: structure of the stratosphere, ozone climatology, stratospheric dynamics, electrodynamics of the middle atmosphere, changes of solar and meteorological origin in the mesosphere and lower thermosphere and turbulence.

In the study of the structure of the stratosphere balloon measurements were carried out regularly at the stations of the State Meteorological Service. The measurements included the determination of temperature, pressure and humidity, as well as the direction and velocity of the winds.

The total ozone content was determined in the Central Institute for Atmospheric Physics by Dobson spectrophotometer. The study of the ozone data is part of a complex investigation of radiation conditions in the middle atmosphere. Data of satellite measurements were also included.

For the study of stratospheric dynamics data of ground based and balloon measurements were used. The periods of stratospheric warmings and seasonal changes were investigated.

Concerning the electrodynamics of the middle atmosphere the atmospheric electric potential gradient and the vertical air-earth current were recorded at the Geophysical Observatory Nagycenk of the Geodetic and Geophysical Research Institute of the Hungarian Academy of Sciences, Sopron. The study of the potential gradient data indicates a relation to the quasi-biennial oscillation QBO, showing a positive and significant correlation between the potential gradient in the winter months and the solar activity (characterized by the solar radio flux $F_{10.7}$) in the west phase of the QBO, while it is inversely related to the solar activity in the east phase (Fig.1) (Märcz, 1989).

Changes of solar and meteorological origin in the mesosphere and lower thermosphere were studied by means of ground-based measurements. The ionospheric absorption of obliquely incident radio waves was measured in the Geophysical Observatory Nagycenk of the Geodetic and Geophysical Research Institute of the Hungarian Academy of Sciences, Sopron. Investigating the phenomena in the lower ionosphere after solar flares in this institute, it has been found that significant reduction of the ionization in the mesosphere occurs due to galactic cosmic ray (Forbush) decreases, if the plasma cloud does not hit the magnetosphere. If the solar flare is followed by geomagnetic disturbances, the effect decreases with increasing geomagnetic activity because of the decrease of the cutoff rigidity. The post storm effect in the lower ionosphere following in time the Forbush effect can be reduced and shifted in time by the ionospheric effect of the Forbush decrease (Fig.2) (Sátori, 1984; 1989). The analysis of the post storm effect indicated that high speed plasma streams associated with solar flares are especially effective in the production of post storm effect the effect depending besides on the maximum velocity on their duration and maximum velocity increase (Märcz, 1988).

For the determination of the turbulent parameters in the lower thermosphere a method has been developed in the Geodetic and Geophysical Research Institute of the Hungarian Academy of Sciences, Sopron. The method is based on the wind-shear theory of mid latitude sporadic E and atmospheric, as

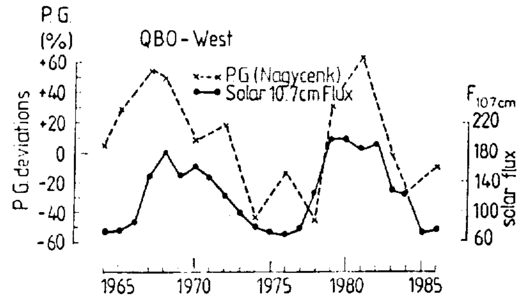


Fig. 1. Potential gradient during the west phase of QBO and solar activity (F. Märcz, 1989, submitted to Ann. Geophysicae)

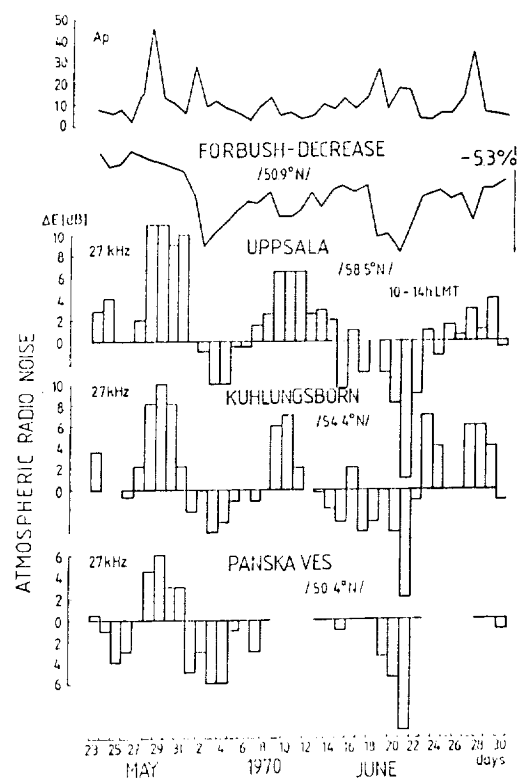


Fig. 2. The effect of Forbush decreases and the geomagnetic post storm effect in atmospheric radio noise (G.Sátori, 1989. submitted to J. atmos.terr.Phys.)

well as ionospheric models (Bencze, 1984). In addition to the Es parameters h'Es and fbEs wind data are also used. The study of the turbulent diffusion coefficient obtained by this method indicates a decrease of turbulence during circulation disturbances associated with stratospheric warmings, as well as a tendency to increased turbulence during sporadic winter anomaly periods in ionospheric absorption and with rising geomagnetic activity (Bencze, 1984; 1988). Similar changes have been found in ionospheric absorption, which could hint at the role of turbulence by the transport of NO in the production of these phenomena (Bencze, 1989).

REFERENCES

Bencze, P., Investigation of aeronomic processes on the basis of ionospheric sporadic E, Handbook for MAP, 10, 179, 1984.

Bencze, P., Turbulence around the turbopause deduced from ionospheric sporadic E for MAP, Adv. Space Res., 4(4), 83, 1984.

Bencze, P., Dynamische Prozesse in der unteren Ionosphäre als Indikatoren der Wechselwirkung zwischen der verschiedenen Schichten der Atmosphäre, Z.Meteorol., 38(2), 103, 1988.

Bencze, P., Interrelation between the different variations of turbulent diffusion and ionospheric absorption originating in the middle atmosphere, Handbook for MAP, 27, 18, 1989.

Märcz, F., Geomagnetic activity and ionospheric absorption associated with high speed plasma streams, Ann. Geophysicae, 6(2), 195, 1988.

Märcz, F., Atmospheric electricity and 11-year solar cycle associated with QBO, Submitted to Ann. Geophysicae.

Sátori, G., and B. Schäning, Solar-terrestrial influences on the D-region as shown by the level of atmospheric radio noise, Handbook for MAP, 10, 205, 1984.

Sátori, G., Combined ionospheric effect due to Forbush decrease and magnetospheric high energy particles at mid-latitudes, Submitted to J.atmos.terr.Phys.

The New International Equatorial Observatory (NIEO)

Susumu Kato
Radio Atmospheric Science Center
Kyoto University
Kyoto 611, JAPAN

(October 26, 1989)

1 Introduction

In March 1982 MAP Steering Committee organized MSG 6 on Scientific Aspects of an International Equatorial Observatory (IEO) with Prof. S. Kato as chairman and seven other members. The General Assembly of IUGG in Hamburg in August 1983 recommended early establishment of the equatorial observatories with MST/ST radars and other relevant facilities (MAP Handbook vol. 23 pp.9-12). Recognizing the importance of the equatorial observatory for scientific study of the equatorial middle atmosphere MSG 6 was developed to a PMP, the New International Equatorial Observatory (NIEO), in November 1984.

NIEO was promoted by Prof. S. Kato as chairman and other members. It was found that LAPAN, (Indonesian Institute for Space and Aeronautics), is interested to invite the equatorial observatories to Indonesia. Then, the practical activity for NIEO became to depend on collaborative efforts between a group of Radio Atmospheric Science Center Kyoto University and that of LAPAN.

Japanese organizations have also been supporting the NIEO project. The Science Council of Japan has founded MAP/MAC Committee in May 1986 to discuss scientific aspects of the NIEO project, and approved the project in February 1987. In July 1987 Japan National Committee for Radio Science, Science Council of Japan also approved the NIEO project.

In response to these demands on the NIEO project supported by various international and Japanese scientific organizations, many people from both Japanese and Indonesian groups have visited each other to discuss the promotion of the NIEO project including the construction of the Equatorial Radar. Finally, the establishment of NIEO including the Equatorial Radar has been approved as a joint project between RASC, BPPT and LAPAN.

The RASC and LAPAN groups have met many times to discuss the promotion of NIEO surveying the candidate sites for a giant equatorial radar, the central facility of

NIEO. The NIEO project was finally accepted as a joint project among RASC in Japan and BPPT (Indonesian Agency for the Assessment and Application of Technology) and LAPAN.

In November 1988, Prof. Dr. Ing. B. J. Habibie, Minister of Research and Technology of Indonesia made a formal visit to Kyoto University and inspected the MU radar of Shigaraki MU Observatory of the Radio Atmospheric Science Center. Prior to the visit, the establishment of NIEO including the Equatorial Radar was supported by Prof. Habibie in May 1987 to be promoted as a joint project between RASC, BPPT and LAPAN. In March 29–31, 1989, Symposium on Indonesia and Global Weather was held by BPPT in Jakarta in the presence of Prof. Habibie with more than 100 participants from Japan, USA and Indonesia. This meeting was so timely to evoke wide appreciations on this project among Indonesian scientists and politicians.

For the construction of the Equatorial Radar, the observatory site must satisfy fairly strict conditions on various requirements as described in later sections. RASC started feasibility study of the Equatorial Radar in April 1982, and visited several candidate places in Indonesia with the participation of Indonesian groups in the last several years.

First site survey to Pontianak in West Kalimantan and Biak island in Irian Jaya was conducted in June 1985 in collaboration with LAPAN. From a simple survey, the location in Biak was found unsuitable, because the land area is too small to locate a large antenna.

The other candidate site near Pontianak is fairly flat, which looked suitable for NIEO. Second and third site survey of Pontianak on radio noise, soil, and meteorological conditions were made in July 1987 and October 1988. Long and serious discussions had been continued in order to find solutions to various technical problems on this location. In spite of these efforts, it has been concluded that the soil condition of the location near Pontianak is not good enough to construct a large observatory, and decided to continue the site survey for NIEO in other area in Indonesia.

During the site survey for NIEO in June–July 1989, we have investigated 14 locations near Bukittinggi in West Sumatera. Because the requirements of the observatory site are stringent, it was not expected that any of the locations could perfectly satisfy all of the candidate sites for the construction of the Equatorial Radar.

At present it is most probable that we can locate the observatory site at Kototabang near Bukittinggi in West Sumatera. In September-October 1989 we have carried out a rainy-season survey and, up to now, we have not found out any problems. However, we shall continue further investigations to fix the plan of the Equatorial radar construction.

2 Equatorial Radar System

2.1 Radar Remote Sensing

Various techniques are available for observing winds globally as well as over a wide altitude range in the earth's atmosphere. These include *in-situ* balloon and rocket soundings, ground-based remote soundings, and the developing technology of satellite-based lidar and other optical measurements. In addition, geostrophic winds are inferred from satellite temperature measurements. Each technique has problems and limitations, and some are well established, while others are new and still being developed. The current most principal techniques are the satellite observations and the ground-based doppler radars.

Global wind measurement will be feasible by using satellite in the next few years. Already tropospheric winds are being obtained on a limited basis by tracking cloud patterns, but the winds are obtained for only one level and only in the areas where clouds are found. By using satellite lidar system, the measurement of tropospheric winds will be possible, but the measurement of stratospheric winds is doubtful. Geostrophic winds can be determined over a range of altitudes which include much of the stratosphere and mesosphere, and coincide with the actual wind whenever the wind field is in balance with the thermal field. However, the geostrophic approximation is valid only away from the tropics and for the large scale of atmospheric motions. At the moment neither good temporal and height resolutions are expected for any of the above-mentioned satellite observations.

On the other hand, the ground-based atmospheric radar observations feature the continuous measurement of winds over a wide range of altitudes from near the ground up to 1000 km with good temporal and altitude resolutions irrespective of weather conditions. However, the covered regions of observations are limited only to narrow areas over the radars. Thus, the satellite and ground-based radar observations should not conflict with each other but essentially be complementary, and no doubt a combination of both techniques should have to be used in the future for more comprehensive understandings of the dynamical structure of the global atmosphere.

The atmospheric radar utilizes a physical principle that the VHF/UHF radiowaves are scattered by refractive index fluctuations in the atmosphere, which are mainly caused by humidity and atmospheric density perturbations due to turbulence in the neutral atmosphere, and primarily by thermal motion of electrons in the thermosphere. The backscattered echo is, however, so weak that the atmospheric radars need intense transmitted power as large as 1 MW and a huge antenna area of the order of about 10,000 m^2.

The atmospheric radar operated at low VHF (~50 MHz) is capable of continuously monitoring the motions of neutral atmosphere ranging from the ground up to about 100 km with time and height resolutions of about 1 min and 100 m, respectively. It also has large potential for the observations of various meteorological disturbances, such as fronts, typhoons, thunderstorms, or even rainfall. The same radar can also observe the detailed characteristics of the ionized atmosphere such as electron density, electron/ion temperature, ion drift velocity, and ion composition in the height range up to about 1000 km.

RASC of Kyoto University has designed and constructed the MU (Middle and Upper atmosphere) radar in 1984, which is at present the most advanced and versatile atmospheric radar in the world. The MU radar is operated at 46.5 MHz with the peak and average transmitted power of 1 MW and 50 kW, respectively. The antenna of the MU radar system is composed of a circular array of 475 crossed three-subelement Yagi antennas, giving the antenna aperture of 8,330 m^2. Each Yagi antenna is activated by an individual solid-state power amplifier, which enables the fast and continuous antenna beam steerability.

It is now widely accepted that the radar remote sensing technique of using a gigantic atmospheric radar enables us to continuously observe the vertical structure of the earth's atmosphere But no such radar yet exists near the equator. In the next subsection, we describe concept design of the Equatorial Radar for observing the whole equatorial atmosphere up to 1000 km altitude, with the system being quite similar to the MU radar, but the antenna area (i.e. the number of antenna elements), hence the number of power-amplifiers, are approximately 10 times larger than that of the MU radar.

2.2 Design of the Equatorial Radar

A brief description of the system design of the Equatorial Radar is presented in this subsection. Figure 1 shows an artist's conception of the Equatorial Radar, while Figure 2 gives a block diagram.

The Equatorial Radar is a monostatic Doppler radar with an active phased array operating at 47 MHz, whose system parameters given in Table 1 are similar to those for the MU radar in Japan. The antenna array is quasi-circular with an aperture of about 70,000 m^2, giving the nominal beam width of 1.2°. The antenna area of the Equatorial Radar is about 10 times larger than that of the MU radar. The array is composed of ~2,940 crossed Yagi antennas, each with 4 subelements. Each crossed Yagi is activated by an individual solid-state transmitter-receiver (TR) module, and these modules are accommodated in seven TR booths located within and around the antenna array. The whole antenna array can be subdivided into ~40 groups. (The exact number of the elements and groups, and hence the outer shape of the array are subject to change in the course of the final system design.)

The peak and average transmitted power becomes about 1.4 MW and 70 kW, respectively. The sensitivity of an atmospheric radar is estimated by the PA product, where P is the average transmitted power and A is the effective antenna area, respectively. The PA product for the Equatorial Radar is $\sim 5 \times 10^9$ Wm^2, which is again approximately 10 times larger than that of the MU radar, and it will be the largest in the world.

Table 1: Basic parameters of the international Equatorial Radar.

Parameter	Value
Radar system	monostatic pulse radar; active phased array system
Operating frequency	47 MHz
Antenna	circular array of ~2,940 crossed Yagi's
aperture	~71,520 m^2 (~302 m in diameter)
beam width	1.2° (one way; half power for full array)
steerability	steering is completed in each IPP
beam directions	0°–20° off zenith angle
polarizations	circular
Transmitter	~2,940 solid state amplifiers (TR modules; each with output power of ~600 W peak and ~30 W average)
peak power	~1.4 MW (maximum)
average power	~70 kW (duty ratio 5%)(maximum)
bandwidth	~2 MHz(maximum) (pulse width: 1–512 μs variable)
IPP	100 μs to 64 ms (variable)
Receiver	
bandwidth	~2 MHz (maximum)
IF	5 MHz
A/D converter	16 bits × 8 channels
Pulse compression	binary phase coding up to 32 elements; Barker and complementary codes

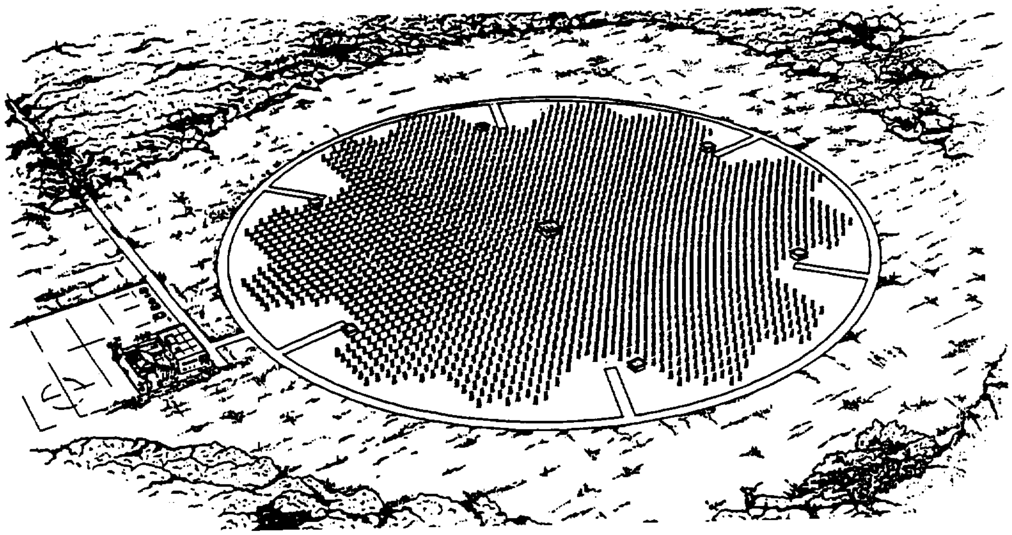


Figure 1: Artist's conception of the Equatorial Radar.

A programmable radar controller supervises the overall operation of the radar, which produces flexibility of the observations. Received signal is processed by a data-handling computer system of suitable design.

The manufacturing cost of the whole radar system including civil engineering of site is estimated as around 16,000 million Japanese yen (120 million US$) as of August 1989. The annual operating costs will amount to 700 million Japanese yen (5 million US$) at the stage of its full operation. The construction and operation are expected to be funded by Japan, but additional funds are expected to come from the USA and other countries. The overall participation of Indonesia as the host is essential to make this project successful.

The research with the Equatorial Radar should be conducted with participation of all who are interested in the equatorial atmosphere research following the spirit of the IUGG recommendation, and the organization or the body responsible for operation of the facilities should be finalized between Japan and Indonesia at the earliest opportunity.

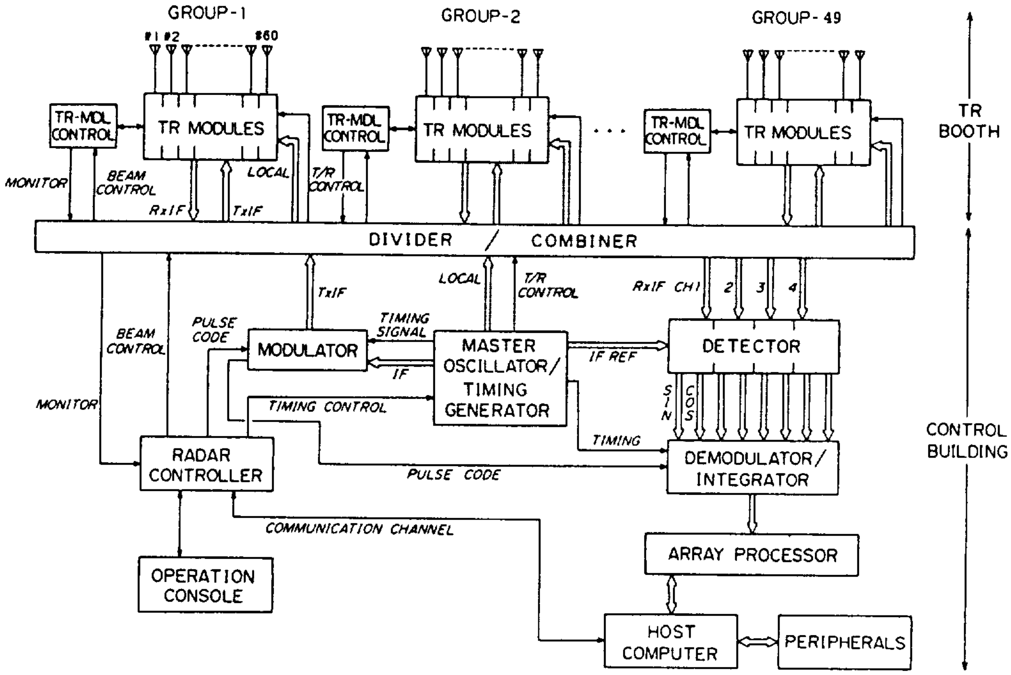


Figure 2: General block diagram of the Equatorial Radar.

MAP ACTIVITIES IN NEW ZEALAND, 1981 - 1989

NEW ZEALAND METEOROLOGICAL SERVICE
(Atmospheric Physics and Chemistry)

Postal Address: P.O. Box 722, Wellington, New Zealand.

Project Scientist: Sylvia Nichol

B. Initially the New Zealand Meteorological Service Dobson spectrophotometer was operated in New Zealand at Invercargill (46.42°S, 168.33°E) from 1970 until September 1987. In January 1988 it was moved to Arrival Heights (77.82°S, 166.67°E) near Scott Base in the Antarctic. In February 1989 a Brewer spectrophotometer was installed at Scott Base (77.85°S, 166.76°E) as a joint project with Instituto Di Fisica Dell' Atmosfera, Rome, Italy.

Both instruments are used to measure the total column ozone daily from September through to March, and during the full-moon periods in the winter. Umkehr vertical ozone distributions are also possible for six weeks each spring and autumn.

The Antarctic ozone measurements at Arrival Heights and Scott Base will continue beyond the end of MAP.

* * * * *

DSIR PHYSICS AND ENGINEERING LABORATORY, LAUDER
(compiled by Gordon Keys)

Postal Address: Lauder, Central Otago 9182, New Zealand

Project Scientists: Paul Johnston
Nicholas Jones
Gordon Keys
Andrew Matthews
Richard McKenzie

A. **Stratospheric Trace Gas Studies:**

1. Studies of twilight stratospheric NO_2 and 0_3 using differential absorption spectroscopy have been made since 1981 at Lauder (45.0°S, 169.7°E). The technique involves the acquisition of grating spectrometer spectra of scattered sunlight in the zenith. Day-to-day and seasonal variability of stratospheric NO_2 have been analysed in terms of the interwoven effects of chemistry and transport, and the results examined in conjunction with ground-based and satellite meteorological data. Measurements were also made on a campaign basis from France during September/October 1985, as part of MAP Globus 85, from Kiruna, Sweden (21°E, 68°N) in January/February 1989, and from the Jungfraujoch Observatory (8°E, 47°N) during March/April 1989.

   NO_2 data acquired from ground-based experiments as above have compared with SAGE satellite data (in conjunction with NASA).

2. From August 1986, regular weekly (and in spring and early summer twice weekly) ozone sonde flights have been made from Lauder with an average burst height of 31 km. In January 1987, an automated Dobson spectrophotometer was installed at Lauder. As well as manual direct sun total ozone observations, this instrument records Umkehr values automatically. It is one of the seven instruments that constitute the "Automated Dobson Network".

3. Direct sun measurements of HNO_3, HCl and other species have been made (in cooperation with University of Denver) using Michelson Fourier Transform spectroscopy in the 3μ and 7-14μ windows for approximately 6 weeks/year from 1985 to present.

4. In January 1989, a vertical profile measurement to 30 km was made of NOy, O_3, HNO_3 and atmospheric aerosol from Kiruna, Sweden (68°N). This experiment was performed in conjunction with Service d'Aeronomie France, and the Universities of Nagoya, Denver and Wyoming.

B. Tropospheric Trace Gas Studies:

Analyses have been made of the sources, sinks and variability of certain species which are of importance in the stratospheric studies, as follows:

1. Long path measurements of NO_2 using the DAS technique with grating spectrographs and viewing distant light sources. Problems such as the rejection of atmospheric flicker have been overcome to give measurements with a detection threshold for NO_2 approaching 15 ppt.

2. In situ-sampling of 0_3 (in cooperation with New Zealand Meteorological Service) and NO/NO_x using chemiluminescent techniques (with University of Nagoya).

C. UV Radiation Studies:

This is a new programme at Lauder.
Aims are to:

1. Measure the absolute spectral irradiance of solar UV (direct and scattered) received at the surface in New Zealand.
   Units: $W\ m^{-2}\ nm^{-1}$
   Range: 290-450 nm
   Resolution: 1 nm.

   A new instrument has been built for this purpose and measurements are currently being made. These can be compared with measurement campaigns in 1980 and 1988.

2. Quantify temporal and geographic variabilities, and identify causes for any differences (e.g. in terms of atmospheric composition).

3. Monitor the integrated erythemal UV flux using an instrument incorporating a filter that mimics the human erythemal response.

4. Apply radiative transfer calculations to inter-compare these measurements and assess our understanding, and hence our ability to predict the effects of changes in atmospheric composition.

D. Antarctic Stratospheric Trace Gas Studies:

The programme involves:

1. Studies of stratosphere slant column NO_2 and O_3 using differential absorption spectroscopy as in (A1) above at Arrival Heights (78°S, 167°E), Halley Bay (76°S, 27°W, in conjunction with British Antarctic Survey), and South Pole Station (in conjunction with GMCC, NOAA).

2. Spring studies of column HNO_3 and HCl at Arrival Heights (in conjunction with the University of Denver).

E. Auroral Radar Backscatter Studies

A doppler radar system (53.5 MHZ) was operated at Slope Point (46.7°S, 169.0°E) until 1985 when the programme was discontinued. Studies included analysis of E-region pulsation phenomena and other disturbance features in the auroral zone electric field.

* * * * *

UNIVERSITY OF OTAGO, PHYSICS DEPARTMENT.

Postal Address: P.O. Box 56, Dunedin, New Zealand

Project Scientists: Richard Dowden (contact person)
Christopher Adams

Lightning-induced Electron Precipitation:

This occurs below 90 km, possibly below 50 km at times. Resulting ionisation forms within a second (usually) and decays in about 30 s. VLF echoes off these ionisation anomalies from subionospheric transmissions (communications and navigation) are generally 10-40 dB weaker than the direct signal but readily measureable (phase and amplitude). Multifrequency measurements at spaced stations enable location of anomalies up to 5000 km from Dunedin.

Preliminary measurements (1988) indicate an active area in north-west Australia where lightning is abundant and where the centre of the inner radiation belt has its geomagnetic footprint.

* * * * *

UNIVERSITY OF CANTERBURY, PHYSICS DEPARTMENT

Postal Address: Private Bag, Christchurch 1, New Zealand.

Project Scientists:
William O.J. Brown
Alan Burns
Grahame Fraser (contact person)
Usman Khan
Bryan Lawrence
Murray Smith
Andre von Biel
Stephen Wood

A. Antarctic mesosphere:

During MAP this department operated a medium frequency (2.9 MHz) partial reflection radar on Ross Island. The observations yield observations of the vertical profiles of electron density and the horizontal wind at selected altitudes in the height range of 40-120 km. The common transmitter and transmitting array are installed at Scott Base (78°S, 167°E); the two independent receiving and recording systems are installed at the electrically quiet site on Arrival Heights. Both sites are close to the McMurdo USARP base. Radar operation will continue beyond MAP.

1. **The electron density measurements** began operation in November 1981 and data has been obtained for most years since then. A self-calibrating polarimeter measures the differential absorption between ordinary and extra-ordinary components of the partially reflected waves. The most surprising result has been the occasional observation of layers of ionisation with a maximum of electron density around 50 km.

2. **The wind measurements** began in November 1982 using the spaced antenna mode. The measurements of mean winds and atmospheric tides have contributed to various MAP, and other, programs such as Atmospheric Tides in the Middle Atmosphere Program, the Global Thermospheric Mapping Study and the Lower Thermosphere Coupling Study. A layer with characteristics similar to the northern Polar Mesosphere Summer Echo has been observed.

   Preliminary measurements of scattering processes using frequency domain interferometry were carried out over the 1988/9 season.

B. The mid-latitude mesosphere:

The medium frequency (2.4 MHz) partial reflection radar at Birdlings Flat (44°S, 173°E), near Christchurch, N.Z. was also operated during MAP. Observations have been made simultaneously with the Antarctic wind radar and have contributed to the same international programs. The radar wind measurements from both sites, together with stratospheric temperature data from satellites, are being used in a study of southern hemisphere planetary-scale waves and their propagation into the mesosphere.

C. Ozone and aerosol measurements

Preliminary measurements have been made in N.Z. and Antarctica with a multi-wavelength interference filter direct-sun photometer to assess total column ozone and aerosol content. Observations included the recovery of ozone column content at Scott Base (78°S, 167°E) in November 1986.

MAP ACTIVITIES IN NORWAY DURING THE PERIOD 1981-1989

Norway contributed to MAP in the period 1981-1989 by active participation in the MAP/WINE campaign in the winter 1983-1984 and through organizing and conducting the MAC/SINE and MAC/Epsilon campaigns in the summer and autumn of 1987. Andoya Rocket Range in North-Norway was the centre of operations for all three campaigns.

MAP/WINE

The results from the MAP/WINE campaign were published in a special issue of the Journal of Atmospheric and Terrestrial Physics, July/August 1987. The campaign studied the middle atmosphere in winter in high latitudes with emphasis on the following topics: Large scale structures and circulation including several stratospheric warmings, structure and composition, waves and turbulence and temperature structure. Norway had instruments on board 10 sounding rockets for studies of turbulence and electric fields. The 10 payloads contained a number of experiments from institutes in Europe and the USA. All 10 payloads were built in Norway and Norway had the overall payload responsibility. Norway also contributed to the campaign with ground-based radar and optical measurements.

MAC/SINE AND MAC/EPSILON

Norway had the overall scientific and operational responsibility for the international MAC/SINE and MAC/Epsilon campaigns. These campaigns had the following aims:

MAC/SINE (Middle Atmosphere Cooperation/Summer in Northern Europe) studied the general circulation and temperature structure as well as waves, turbulence and winds in high latitudes during summer solstice conditions. The experiments comprised a series of regular meteorological rocket firings and ground-based observations as well as four launches of sounding rockets. The campaign was carried out in June-July 1987.

MAC/Epsilon was a case study of middle atmosphere turbulence by means of instrumented sounding rockets, meteorological rockets and ground-based observations. The campaign comprised four salvoes in which all rocket and ground-based techniques were concentrated in time and space to make detailed measurements during events with strongly developed turbulence. During the campaign period the ground-based techniques were exploited to map the general behaviour of the middle atmosphere during autumn/early winter conditions. The campaign was carried out in October-November 1987.

Both campaigns were very successful and the first scientific results will be published in 1990 in a special issue of the Journal of Atmospheric and Terrestrial Physics containing 21 articles. More than 30 groups from 12 countries in Europe and North America took part in the projects.

Apart from the scientific and operational responsibility for planning and conducting the campaigns, Norway had payload responsibility for five instrumented sounding rockets launched during the Epsilon campaign. These payloads were built in Norway and contained instruments from a number of European groups. Norway also contributed by radar and optical measurements during the campaigns. The EISCAT radar gave particularly valuable results.

MAP ACTIVITIES IN THE USSR

G.M.Grechko

Chairman of the National MAC Commission
Institute of Atmospheric Physics, Academy of Sciences, Moscow, USSR

In 1979 the Presidium of the Academy of Sciences of the USSR took a decision on the participating of Soviet scientists in the Middle Atmosphere Program. The Soviet National MAP Commission was established under the auspices of the Soviet Geophysical Committee, in 1986 it was reorganized to the National MAC Commission. About 40 Soviet scientific institutions of the Academy of Sciences, State Committee on Hydrometeorology and the Ministries of Higher Education took part in the carrying out the MAP and MAC. The outline of the Soviet MAP programme (Danilov et al.,1981), and the intermediate report about MAP activities in the USSR (Danilov et al., 1985) have appeared in the Handbook for MAP. Some brief reviews of recent results of Soviet MAP studies may be found in the Handbook for MAP, 27.

Soviet MAP programme was concentrated on the directions where traditionally strong scientific schools with the corresponding experimental equipment take place. The main directions were: stratospheric and mesospheric studies with the meteorological rockets; ground observations of the lower ionosphere by radiophysical methods; observations of dynamics of mesosphere and lower thermosphere by radiophysical methods and by meteor trail radiolocations; theoretical and experimental studies of the tides, of the generation and propagation of the planetary and internal gravity waves; investigation of the interaction between the different layers of the atmosphere; studies of the dynamics of the ozone layer. The USSR have participated in about ten MAP projects. Some of the main results of the Soviet MAP studies are briefly described below.

Soviet scientists made the significant contribution to the investigation of the dynamical processes in the middle atmosphere during MAP/MAC. They were the initiators and participants of the GLOBMET project, which was intended to coordinate on the globe scale wind studies in the mesosphere and lower thermosphere by meteor trail radiolocation method. The main results of studies of the dynamical processes in the lower thermosphere by radiometeor method in the USSR under MAP and GLOBMET programmes are reviewed by Kashcheev and Lysenko (1989).

The new important results were obtained for the same height interval by studies of the longitudinal variations of the atmospheric dynamics. Comparison of measurements in the American region, Europe, and Siberia have shown that there are significant variations of dynamical regime, which confirm the conception of nonzonality of the middle atmosphere (Kazimirovsky and Vergasova, 1989; Danilov et al., 1987).

During the MAP/MAC period the lidar station at the Heiss island ($80^{\circ}37'$ N) was used in the experimental studies. This station works from 1975 and allows to measure the height distribution of mesospheric sodium. The data sets was analysed to obtain seasonal and space-time variations of Na layer (Tulinov et al., 1989).

New interesting results in the internal gravity wave studies were obtained in the recent years by the optical methods of the registration of the own lower thermosphere radiation of OH, O, Na (Semenov and Shefov, 1989).

Soviet MAP programme proposed the analysis and generalization of all experimental data by constraction the reference models of the middle atmosphere. The project of such model is described by Koshelkov (1986), Glazkov et al. (1986), Ivanovsky et al. (1989).

During the past decade a significant progress was achived in the investigating of the ionospheric D region. The works of the Soviet scientists reviewed by Danilov (1989) made the essential contribution, especially in the understanding and formulating the conseption of the meteorological control of the D region and possible mechanisms of its realization (Danilov and Taubenheim, 1983; Danilov, 1986).

In the winter of 1983/1984, the research institutes of the USSR took an active part in the accomplishment of the project MAP/WINE. The Soviet contributions were very considerable. Eight institutes were directly involved in the coordinated experimental study. Different methods - ground-based, satellite, rocket - were used to measure temperature, direction and velocity of wind, turbulence, electron concentration in the lower ionosphere, and radio wave absorbtion. The study of the stratospheric warmings and the related changes in the mesosphere and lower ionosphere was considered of special importance. More than 250 meteorockets were launched from the ranges of the USSR and Scandinavia, about half of them from the Soviet ranges Volgograd and Heiss island. Besides, rockets from Bulgarian range Akhtopol were launched with the assistance of the USSR.

The analysis of the obtained data has shown, in particular, that during the stratospheric warmings the westerly wind in wintertime becomes weaker and even reverses. At the same time period the electron concentration and the radiowave absorption in the lower ionosphere are often reduced. It is also observed that the high absorption zones move from west to east. These results confirm the consept about the role of the cyclonic circumpolar vortex in the transport of the auroral air to temperate latitudes and about the appearance of conditions for the winter anomalous radio wave absorption. Soviet contributions to the MAP/WINE are reviewed by Rapoport (1989) and are reflected in a series of papers, e.g. Belikovich et al. (1986), Bugaeva et al. (1986), Grossmann et al. (1987), Kokin (1984), Kokin and Pakhomov (1985), Kokin and Pakhomov (1986), Kokin et al. (1985), Labitzke et al. (1987), Luebken et al. (1987), Matveeva and Semenov (1986a), Matveeva and Semenov (1986b), Nestorov et al. (1986), Pakhomov et al. (1986), Rapoport (1984), Rapoport and Kazimirovsky (1989), Sachariev et al. (1986), Williams et al. (1987).

In 1989, November 12-19, the Soviet MAC Commission has organized the International Symposium on Middle Atmosphere Studies in Dushanbe, USSR, where the results in many directions of MAP activities, recent progress and future plans were discussed.

REFERENCES

Belikovich, V.V., E.A. Benediktov, N.P. Goncharov, L.V. Grishkevich, and V.D. Vyakhirev, A study of the winter-time D-region using the partial reflection technique, J. Atmos. Terr. Phys., 48, 1241-1245, 1986.

Bugajeva, I.V., D.A. Tarasenko, and L.A. Rjasanova, Large scale processes and energetic characteristics of the stratosphere during the MAP/WINE experiment, Meteorology and Hydrology, 6, 21-25, 1986.

Danilov, A.D., Meteorological control of the D region, Ionospheric Researches, No. 39, Study of the middle atmosphere, 33-42, Moscow, 1986.

Danilov, A.D., Achivements in studying the D region during the MAP period, Ionospheric Researches, No. 47, Middle atmosphere studies, 78-95, Moscow,

1989.
Danilov, A.D., E.S. Kazimirovsky, G.V. Vergasova, and G.Ya. Khachikyan, Meteorological effects in the ionosphere, Leningrad, 1987.
Danilov, A.D., E.S. Kazimirovsky, and V.V. Viskov, Studies in the USSR relevant to MAP, Handbook for MAP, 1, 61-65, 1981.
Danilov, A.D., E.S. Kazimirovsky, and V.V. Viskov, MAP activities in the USSR, Handbook for MAP, 17, 143-145, 1985.
Danilov, A.D., and J. Taubenhiem, NO and temperature control of the D-region, Space Sci. Rev., 34, 413-423, 1983.
Ivanovsky, A.I., V.V. Fedorov, and V.N. Glazkov, The main results of studying the thermodynamic parameters and circulation of the middle atmosphere, Ionospheric Researches, No. 47, Middle atmosphere studies, 62-77, Moscow, 1989.
Glazkov, N.N., A.I. Ivanovsky, V.V. Fedorov, L.V. Shcherbakova, and E.N. Kovshova, An analitical method for describing the fields of meteorological parameters and the results of their application to simulating the structure and circulation of the Earth's middle atmosphere, Ionospheric Researches, No. 39, Study of the middle atmosphere, 52-60, Moscow, 1986.
Grossmann, K.U., H.G. Bruckelmann, D. Offermann, P. Schwabbauer, R. Gyger, K. Kunzi, G.K. Hartmann, C.A. Barth, R. Thomas, A.F. Chijov, S.P. Perov, V.A. Yushkov, P. Glode, and K.H. Grasnick, Middle atmosphere abundances of water vapor and ozone during MAP/WINE, J. Atmos. Terr. Phys., 49, 827-841, 1987.
Kashcheev, B.L., and I.A. Lysenko, Studies of the dynamics of the lower thermosphere by radiometeor methods, Ionospheric Researches, No. 47, Middle atmosphere studies, 44-61, Moscow, 1989.
Kazimirovsky, E.S., and G.V. Vergasova, Meteorological effects in the dynamics of the lower thermosphere, Ionospheric Researches, No. 47, Middle atmosphere studies, 11-23, Moscow, 1989.
Kokin, G.A., Experimental studies data on MAP in 1983-84 winter, Central Aerological Observatory Report, 183 pages, State Committee of the USSR for Hydrometeorology and Control of Natural Environment, Moscow, 1984.
Kokin, G.A., and S.V. Pakhomov, Complex investigations of the middle atmosphere during the winter 1983-84, Meteorology and Hydrology, 7, 107-109, 1985.
Kokin, G.A., and S.V. Pakhomov, Turbulent conditions in the D layer during the winter 1983-84, Geomagnetism and Aeronomy, 26, 714-717, 1986.
Kokin, G.A., I.V. Bugajeva, L.A. Rjasanova, D.A. Tarasenko, and A.I. Butko, Preliminary analysis of processes in the middle atmosphere during the experiment "Winter in the Nothern Europe" (1983/84), Meteorology and Hydrology, 6, 38-43, 1985.
Koshelkov, Yu.P., Observed winds and temperatures in the Southern hemisphere, Handbook for MAP, 16, 15-35, 1986.
Labitzke, K., A.H. Manson, H.G. Mueller, Z.Ts. Rapoport, and E.R. Williams, Hemispheric synoptic analysis of 95 km winds during the winter of 1983/84 and comparison with stratospheric parameters, J. Atmos. Terr. Phys., 49, 639-648, 1987.
Luebken, F.-J., U. von Zahn, E.V. Thrane, T. Blix, G.A. Kokin, and S.V. Pakhomov, In-situ measurements of turbulent energy dissipation rates and eddy coefficients during MAP/WINE, J. Atmos. Terr. Phys., 49, 763-775, 1987.
Matveeva, O.A., and A.I. Semenov, The results of hydroxyl emission observations during MAP/WINE period; stratospheric warming (February 1984), Newsleteer, Middle Atmosphere Program, New Delhi, Aruna Printing Press, No. 3, 4-6, 1986a.
Matveeva, O.A., and A.I. Semenov, Temperature variation in mesopause during stratospheric warming, Geomagnetism and Aeronomy, 26, 331-333, 1986b.
Rapoport, Z.Ts., Measurements of middle atmosphere parameters in the USSR under the MAP/WINE project: Data directory, Soviet Geophysical Committee, Academy of Sciences of the USSR, Moscow, 1984.

Rapoport, Z.Ts., Stratospheric warmings, the circulation of the atmosphere and the absorption of radio waves in the lower ionosphere, Ionospheric Researches, No. 47, Middle atmosphere studies, 96-119, Moscow, 1989.
Sachariev, W., M. Martinov, L. Milenkova, and L.A. Rjasanova, Characteristics of the processes above southeastern Europe in the winter of 1983/84, Problems of Meteorology and Hydrology, No. 6, Publ. BAN, Sofia, 1986.
Semenov, A.I., and N.N. Shefov, The effect of internal gravity waves on the dynamics and energetics of the lower thermosphere, Ionospheric Researches, No. 47, Middle atmosphere studies, 24-43, Moscow, 1989.
Tulinov, G.F., Yu.P. Dudoladov, M.S. Ivanov, K.L. Zinovjev, and M.L. Chanin, On the variations of the total sodium content in the mesosphere of the Central Arctic, Ionospheric Researches, No. 47, Middle atmosphere studies, 137-145, Moscow, 1989.
Williams, E.R., G.M. Watkins, T.A. Blix, E.V. Thrane, G. Entzian, G. von Cossart, K.M. Greisiger, W. Singer, J. Taubenheim, M. Friedrich, C.M. Hall, J.R. Katan, J. Lastovicka, B.A. de La Moreno, S.V. Pakhomov, H. Ranta, Z.Ts. Rapoport, V.M. Sinelnikov, D. Samardjiev, G. Nestorov, H.H. Sauer, and P. Stauning, The ionosphere: morphology, development and coupling, J. Atmos. Terr. Phys., 49, 777-808, 1987.

European Fireball Network

MAP DATA CATALOGUE.

1. SUBJECTS: Disturbances of the Atmosphere at Heights of 120 to 40 km by Penetration of Meteoroids of Metre and Decimetre Dimensions

2. PRINCIPAL INVESTIGATOR: Dr. Zdeněk Ceplecha

3. AFFILIATION: Astronomical Institute of the Czechoslovak Academy of Sciences

4. ADDRESS: 251 65 Ondřejov, Czechoslovakia

5. TELEPHONE: Praha 72 45 25 6. TELEX: 121579 ASTR C

7. INSTRUMENTS: All-sky cameras and fish-eye cameras with timing by rotating shutter, each of 42 cameras located at each of 42 stations of the European Fireball Network at mutual distances of the neighbouring stations 90 km apart on an average.

8. OBSERVED PARAMETERS:
   Direct: Distances of time marks along the fireball trajectory and heights, light curves.
   Derived: Velocities, decelerations, ablation coefficients, air densities, orbits.

9. PERIOD OF TIME: Each clear night in the whole MAP period.

10. STATIONS: (see 7.)

11. RESOLUTION AND ACCURACY: ±1 minute of arc in positions over the whole sky hemisphere corresponding to average of ± 50 m in distances, and ± 3% in relative air densities over 10 km height interval.

12. DATA EXAMPLE: See SEAN Bull. 9 (1984), No. 8, p. 17.

13. DATA FORMAT: Only print-outs of the data are available

14. NOTES: Tables formated IBM (DCB = (RECFM = FB, LRECL = 80, BLKSIZE = 800) are in preparation.

FINNISH MAP DATA

1. SUBJECT: IONOSPHERIC ABSORPTION, RIOMETER MEASUREMENTS

2. PRINCIPAL INVESTIGATOR(S): HILKKA RANTA

3. AFFILIATION: GEOPHYSICAL OBSERVATORY

4. ADDRESS: SF-99600 SODANKYLÄ, FINLAND

5. TELEPHONE: (9)693-12226   6. TELEX: 37254 gefso sf

7. INSTRUMENT(S) OR SYSTEM: RIOMETER NETWORK

8. OBSERVED PARAMETER(S): IONOSPHERIC ABSORPTION

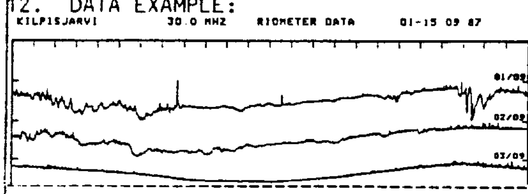
9. PERIOD OR TIME: CONTINUOUSLY

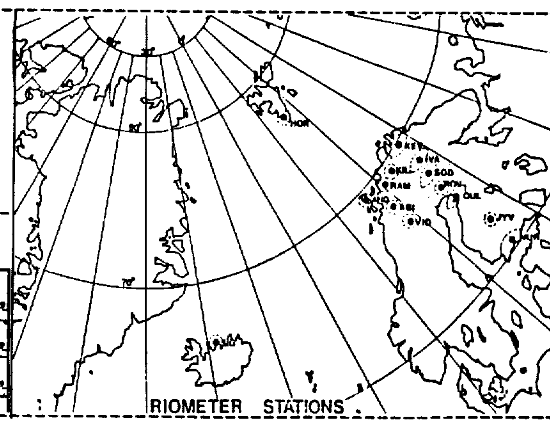
10. STATION: SEE THE MAP

11. RESOLUTION AND ACCURACY:

TIME RESOLUTION 1 MIN

12. DATA EXAMPLE:





13. DATA FORMAT:

14. NOTES: The recordings are scaled every month at the Sodankylä Geophysical Observatory (SGO). Monthly bulletins are published by the SGO. These include the following information (1) absorption at the first minute of each hour (2) maximum absorption during each hour (3) monthly histograms of mean hourly and daily absorption values.

FINNISH MAP DATA

1. SUBJECT: INCOHERENT SCATTER RADAR INVESTIGATIONS OF D-REGION

2. PRINCIPAL INVESTIGATOR(S): ESA TURUNEN

3. AFFILIATION: GEOPHYSICAL OBSERVATORY

4. ADDRESS: SF-99600 SODANKYLÄ, FINLAND

5. TELEPHONE: (9)693-12226 6. TELEX: 37254 gefso sf

7. INSTRUMENT(S) OR SYSTEM: EISCAT

8. OBSERVED PARAMETER(S): ELECTRON NUMBER DENSITY
PLASMA DRIFT VELOCITY
MEAN ION MASS
NEGATIVE ION TO ELECTRON DENSITY RATIO

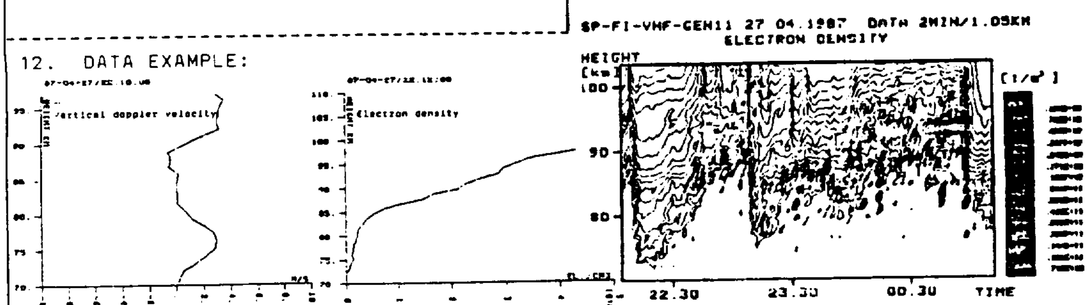
9. PERIOD OR TIME: SPECIAL 1-DAY CAMPAIGNS

10. STATION: TROMSO, NORWAY

11. RESOLUTION AND ACCURACY:

10s-5min/1.05km

12. DATA EXAMPLE:



13. DATA FORMAT: NCAR

14. NOTES:

ORIGINAL PAGE IS
OF POOR QUALITY

MAP DATA CATALOGUE

1 *SUBJECT(S)* : Temperature measurements in the altitude range 30-90 km

2 *PRINCIPAL INVESTIGATOR(S)* : Dr Marie-Lise CHANIN and Alain HAUCHECORNE

3 *AFFILIATION* : Service d'Aéronomie du CNRS

4 *ADDRESS* : BP 3 91371 Verrières le Buisson - France

5 *TELEPHONE* : (1) 69 20 07 94 / 64 47 42 88
Telex 602 400
Telefax (1) 69 20 29 99

6 *INSTRUMENT* : Rayleigh lidar at 532 nm

7 *OBSERVED PARAMETERS* : Density (relative) and temperature (absolute)

8 *PERIODS OR TIME:* OHP Operationnal at nightime since 1981 (100 nights/year)
BIS " " 1986 (" ")
BIS " at daytime 1988 (sporadically)

9 *STATIONS* : Observatoire de Haute Provence : 44°N 6°E (OHP)
Biscarosse 44°N 1°W (BIS)

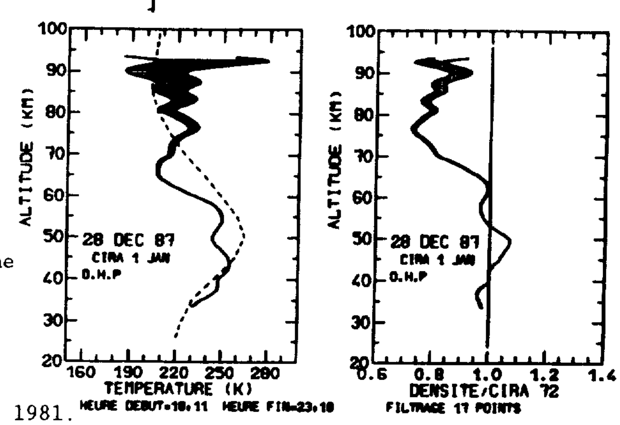
10 *RESOLUTION and ACCURACY* :
Limits of measurements : 30 to 90 km
Limits of resolution : Δz = 300 mètres
Δt = 15 minutes up to 75 km
1 hour up to 90 km
Accuracy : 1 % in density at 70 km
10 % " " 90 km
1 K in temperature at 55 km
10 K " " 85 km
for Δz = 1.2 km, Δt = 1 hour

11 *DATA EXAMPLE* :
Vertical profiles of density and temperature for Δt = 4 hours
Δz = 3 km
obtained at OHP on Dec. 28 1987

12 *DATA FORMAT* : Formatted tables
code ANSI

13 These data are obtained on a routine basis, weather permitting.

14 Description of the method can be found in : CHANIN HAUCHECORNE, Map Handbook, 13, 87, 99, 1984
or J. Geophys. Res., 86, 9715-9721, 1981.



1. MAP DATA CATALOG

Subject. O_3,HF,HCl,N_2O observations by high resolution IR spectrometer.

2.
Principal investigator : Dr A. Barbe

3.
Affiliation : spectrométrie moléculaire et atmosphérique

4.
Address: Université de Reims.BPn°347-51062 Reims Cédex-France.

5.
Téléphone : 26.05.32.58

7.
Instrument. SISAM spectrometer
(0,02cm-1 resolution,1700-4000cm-1range).

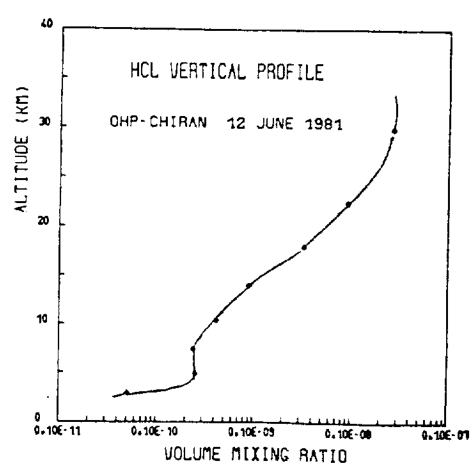
8.
Observed parameters:
a) total ozone concentration
b) HF,HCl,N_2O total concentration
c) HF, HCl, N_2O vertical profiles.

9.
Period of time :
During campaigns of MAP Globus.

10.
Station
Observatoire de Haute-Provence-France. 44°N,6°E

11.
Resolution and accuracy
Total concentration 3%
Vertical distribution - N_2O : 5 km shells
HF,HCl: 7 km shells

12.
Data example.



MAP DATA CATALOG

1.
Subject : O_3 observations by Dobson spectrophotometer

2.
Principal investigators:DrA. Barbe and M.F.Merienne

3.
Affiliation: Spectrométrie moléculaire et atmosphérique.

4.
Adress: Université Reims - BPn°347-51062 Reims Cédex-France.

5.
Telephone : 26.05.30.00

7.
Instrument : Dobson spectrophotometer

8.
Observed parameters:
a) Total ozone concentration given in Dobson Units (20 measurements per day).
b) Vertical distribution of O_3 by Umkehr method during sunrise and sunset.

9.
Period of time:
Every day since 10/3/83, when weather permits it.

10.
Station:
Observatoire de Haute Provence - France. 44°N,6°E

11.
Resolution and accuracy
a) Total ozone - relative value 2%
- absolute value 5%
b) Vertical distribution : 13 shells of 5 km

12.
Data examples.

```
17  1 1987 (1)        OZONE TOTAL:  274 unites DOBSON
 21.6  17.1  22.9  50.9 106.9 113.3  86.1 49.90 20.60  6.50  1.79  0.49  0.13

17  1 1987 (2)        OZONE TOTAL:  274 unites DOBSON
 19.8  15.7  22.0  48.5 109.2 119.1  89.7 49.00 18.90  5.90  1.66  0.47  0.13

18  1 1987 (1)        OZONE TOTAL:  266 unites DOBSON
 19.6  15.1  20.4  46.9 106.2 114.5  85.5 48.50 19.90  6.30  1.75  0.48  0.13

18  1 1987 (2)        OZONE TOTAL:  266 unites DOBSON
 18.6  14.2  18.5  44.0 106.8 119.2  90.2 48.30 18.20  5.70  1.60  0.46  0.13

19  1 1987 (1)        OZONE TOTAL:  266 unites DOBSON
 20.2  15.6  21.6  48.8 106.1 112.5  84.3 48.00 19.50  6.20  1.73  0.48  0.13

19  1 1987 (2)        OZONE TOTAL:  266 unites DOBSON
 20.1  15.4  20.8  47.4 105.9 114.4  87.3 47.80 18.20  5.70  1.59  0.46  0.13
```

13.
Data format : Flopy disk.

MAP DATA CATALOGUE

1. SUBJECT: Stratospheric and mesospheric ozone profiles above 35 km

2. PRINCIPAL INVESTIGATOR(S): Dr. Jérôme de La Noë, Jean Brillet

3. AFFILIATION: Observatoire de Bordeaux, Université de Bordeaux 1

4. ADDRESS: B.P. 21, Avenue Pierre Sémirot, 33270 Floirac, France

5. TELEPHONE: 56 86 43 30 | 6. TELECOPY: 56 40 42 51

7. INSTRUMENT(S) or SYSTEM: 2.5 m radiotelescope and cooled heterodyne receiver in the frequency band : 80-120 GHz.

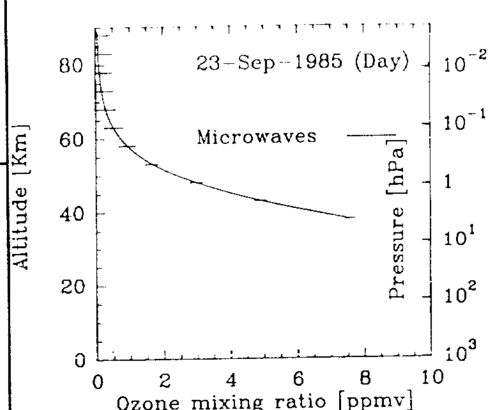
8. OBSERVED PARAMETER(S): Spectral line of Ozone at 110.836 GHz due to thermal radiation by the $0_{0,6}$ - $0_{1,5}$ rotational transition in its fundamental vibrational state.

9. PERIOD or TIME: **1982** Feb. 04-07, Mar. 25-26, Apr. 05-06, Apr. 25-28, May 30-31. **1983** Feb. 17-22, Mar. 03-11, Apr. 13-15, Aug. 29-31, Sep. 01-02, Sep. 04-30, Oct. 01-02. **1984** Apr 09-10.
1985 Feb 18-19, Mar. 07-08, Apr. 01-04, Jun. 07-10, Jun. 25-28, Jul. 01-03, Sep. 09-25, Sep. 27, Oct 04, Oct 21-23, Dec. 12-16.
1986 Feb. 10-13, Mar. 10-13, Apr 28-30, May 21-23, Jul. 15-18, Oct 16-17, Dec. 16-17.
1987 Mar. 03-07, May 19-22, Jun 05-06, Jun 29-30, Jul. 02-03, Sep. 21-25, Sep. 27-30, Oct. 01-02, Nov. 25-30, Dec. 14-16.

10. STATION: Observatoire de Bordeaux (45° N, 0.5° W)

11. RESOLUTION AND ACCURACY:
Vertical resolution is about 10 km ;
Accuracy is : ± 1% at 40 km, ± 150 % at 85 km for r.m.s. noise $\Delta T = 0.05$ K
: ± 6% at 40 km, ± 600 % at 85 km for r.m.s. noise $\Delta T = 0.15$ K

12. DATA EXAMPLE: Vertical profile of ozone mixing ratio above 35 km expressed in ppmv, plotted against the altitude. The vertical profile is retrieved from the observed spectral line according to model-fitting computations (least-squares statistical standard analysis, χ^2 tests) using an analytical expression for the ozone density (Shimabukuro *et al.* 1977, J. appl. Met. **16**, 934).



13. DATA FORMAT: DEC PDP11 and VAX11; sequential formatted files.

14. NOTES: (i) The observationsarecontinuing on the basis of 4 to 6 day per month, 24 hours a day, weather permitting. (ii) The data may be released for joint work with investigators responsible of other types of observations. (iii) Details of the instrument and used techniques may be found in :Brillet, J. 1988, J. Geophys. Res. (submitted) : "A theoretical study of ozone measurement made by ground-based sensors." ; in de La Noë *et al.* 1987, Planet. Space Sci. **35**, 547 : "Remote and ground-based measurements of ozone profiles during the MAP/GLOBUS 1983 Campaign" and in de La Noë *et al.* 1988, J. Atmos. Chem. (submitted) : "Comparison of stratospheric and mesospheric ozone profiles obtained by ground-based and satellite observations."

GDR MAP DATA CATALOGUE 1

1. **SUBJECT:** Meteor radar wind observations

2. **PRINCIPAL INVESTIGATOR:** Dr. K. M. Greisiger

3. **AFFILIATION:** Heinrich-Hertz-Institute of Atmospheric Research and Geomagnetism, Academy of Sciences of the GDR, Observatory of Atmospheric Research Kuhlungsborn

4. **ADDRESS:** Mitschurinstr. 4-6, Kuhlungsborn, DDR-2565, German Democratic Republic

5. **TELEPHONE:** 008293 576 6. **TELEX:** 31263 obskb dd

7. **INSTRUMENT:** Coherent-pulse radar at 32.5 MHz, pulse peak power 20 kW, pulse width 33 us. Probing simultaneously towards N and towards E, 5-element Yagi-antennas.

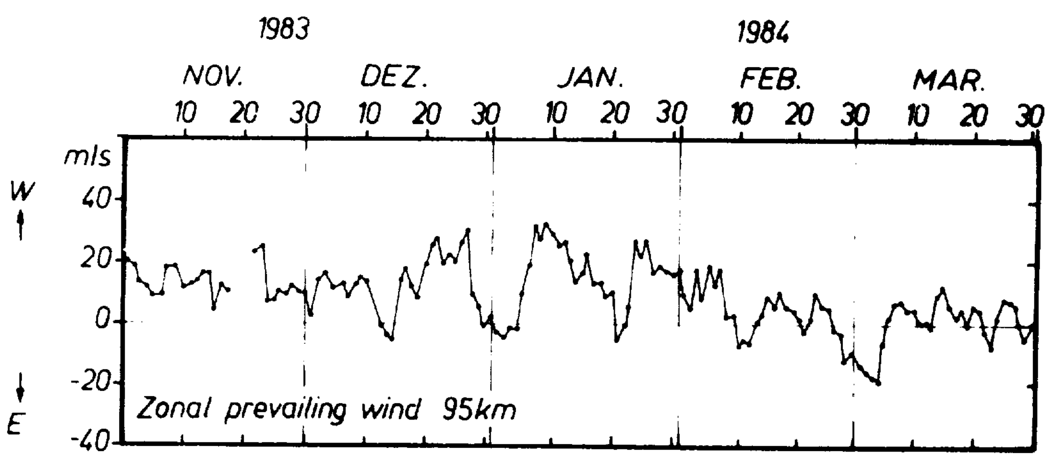
8. **OBSERVED PARAMETERS:** Wind velocities from Doppler shift and echo range (assuming a mean echo height of 95 km), zonal (E-W) and meridional (N-S) component. Regularly half hourly means, the daily mean and the first and second harmonic are determined.

9. **PERIOD OR TIME:** Since 1976, regularly every Tuesday and Wednesday, continuous observations during international campaigns, especially in the winters 1978/79 to 1986/87.

10. **STATION:** Observatory Kuhlungsborn (54.12° N, 11.77° E)

11. **RESOLUTION AND ACCURACY:** No height resolution, accuracy of half hourly mean values 2 - 3 m/s.

12. **DATA EXAMPLE:** Interdiurnal variation of the zonal prevailing wind in winter 1983/84.



13. **DATA FORMAT:** Tables of prevailing wind, diurnal and semi-diurnal tidal winds (amplitude and phase), daily values, monthly mean values.

GDR MAP DATA CATALOGUE 2

1. **SUBJECT:** Indirect Phase Height Observation

2. **PRINCIPAL INVESTIGATORS:** Prof.Dr.G.v.Cossart, Dr.G.Entzian

3. **AFFILIATION:** Heinrich-Hertz-Institute of Atmospheric Research and Geomagnetism, Academy of Sciences of the GDR, Observatory of Atmospheric Research Kuhlungsborn

4. **ADDRESS:** Mitschurinstr. 4-6, Kuhlungsborn, DDR-2565, German Democratic Republic

5. **TELEFONE:** 008293 576 6. **TELEX:** 31263 obskb dd

7. **INSTRUMENT:** Phase height analysis from amplitude measurements of long distant LF-transmitters (f = 163.8 kHz and 155 kHz, distances: 1023 km, 1359 km respectively, reflection points: 50.7°N, 6.6°E; 50.1°N, 19.3°E) and VLF-transmitter (f = 50.0 kHz, distance: 498 km, reflection point: 52.1° N, 13.5°E).

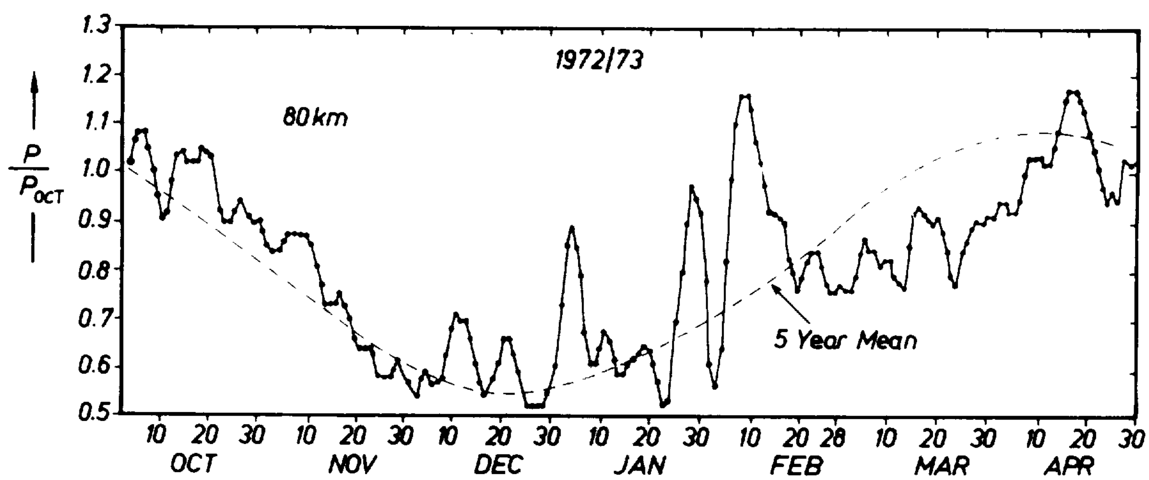
8. **OBSERVED PARAMETERS:** Occurrence time of discrete reflection heights (during daytime only), interpreted as height of a constant electron density level of about 450 el/cm^3(LF) or 250 el/cm^3(VLF). Derived information on a) short time reflection height change by solar eruptions; monitoring of solar eruptions. b) diurnal reflection height change; monitoring of interdiurnal, seasonal and interannual atmospheric pressure variation at 80 km.

9. **PERIOD OR TIME:** LF: Since 1959 (155 kHz only to 1985); VLF: Since 1967

10. **STATION:** Observatory Kuhlungsborn (54.12° N, 11.77° E)

11. **RESOLUTION AND ACCURACY:** Absolute height accuracy about 3 km; Resolution of height change during solar eruption: about 0.5 km.

12. **DATA EXAMPLE:** Interdiurnal pressure variation normalised to the mean pressure of October in 80 km during winter 1972/73. Note the response to stratwarm event Jan/Feb 1973.



13. **DATA FORMAT:** Tables of daily values of Chapman function of solar zenith angle at constant reflection height (80 km).

GDR MAP DATA CATALOGUE 3

1. **SUBJECT:** Ionospheric LF-absorption at oblique incidence (A3-Method)

2. **PRINCIPAL INVESTIGATOR:** Dr.J.Bremer

3. **AFFILIATION:** Heinrich-Hertz-Institute of Atmospheric Research and Geomagnetism, Academy of Sciences of the GDR, Observatory of Atmospheric Research Kuhlungsborn

4. **ADDRESS:** Mitschurinstr. 4-6, Kühlungsborn, DDR-2565, German Democratic Republic

5. **TELEFONE:** 008293 576 6. **TELEX:** 31263 obskb dd

7. **INSTRUMENTS:** Fixed frequency receivers with loop aerials

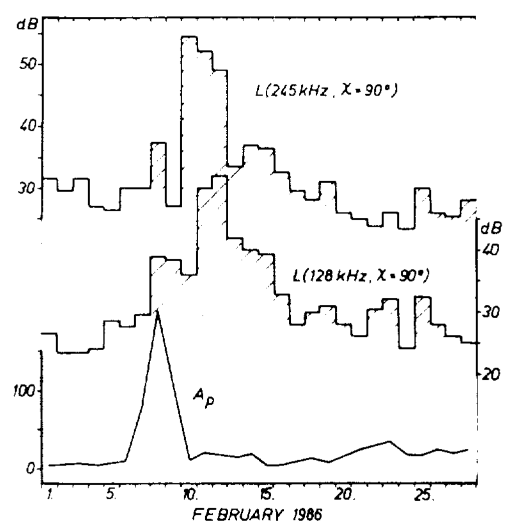
8. **OBSERVED PARAMETER:** Ionospheric LF -absorption at oblique incidence (A3-Method) in dB for 3 different measuring paths(f=128 kHz, d=220 km; f=177 kHz, d=180 km; f=245 kHz, d=180 km), absorption data are estimated at constant solar zenith angles (chi = 78.5°, 90°) as well as night-time conditions (chi $\geq$ 100°)

9. **PERIOD OR TIME:** Continuous measurements at 245 kHz since 1948, at 177 kHz (at the beginning 185 kHz) since 1952 with interruptions, at 128 kHz since 1968

10. **STATION:** Observatory Kuhlungsborn (54.12° N, 11.77° E)

11. **RESOLUTION AND ACCURACY:** The averaging times to estimate absorption data at constant solar zenit angles are 20 min (245 kHz, 177 kHz) or 40 min (128 kHz). The accuracy of the derived data is about ± 3 dB.

12. **DATA EXAMPLE:** Variation of ionospheric LF -absorption during and after the geomagnetic disturbance on February 8, 1986 (post-storm-event).



13. **DATA FORMAT:** Printed tables, since 1989 data also available on discette.

14. **NOTES:** (i) The LF- absorption measurements are continuing, (ii) for details of the A3-measurements see: K.Rawer, Manual on ionospheric absorption measurements, Report UAG-57, WDC-A for Solar-Terrestrial Physics, 1976

GDR MAP DATA CATALOGUE 4

1. **SUBJECT:** Ionospheric MF -absorption at vertical incidence (A1-Method) and lowest frequency (fmin) detected by ionosonde measurements.

2. **PRICIPAL INVESTIGATOR:** J.Weiss

3. **AFFILIATION:** Heinrich-Hertz-Institute of Atmospheric Research and Geomagnetism, Academy of Sciences of the GDR, Ionosonde Station Juliusruh

4. **ADDRESS:** Breege, DDR-2338, German Democratic Republic

5. **TELEFONE:** 008276 296 6. **TELEX:** 31522 iss dd

7. **INSTRUMENTS:** Vertical-absorption measurement equipment at 2.0 MHz, Ionosonde

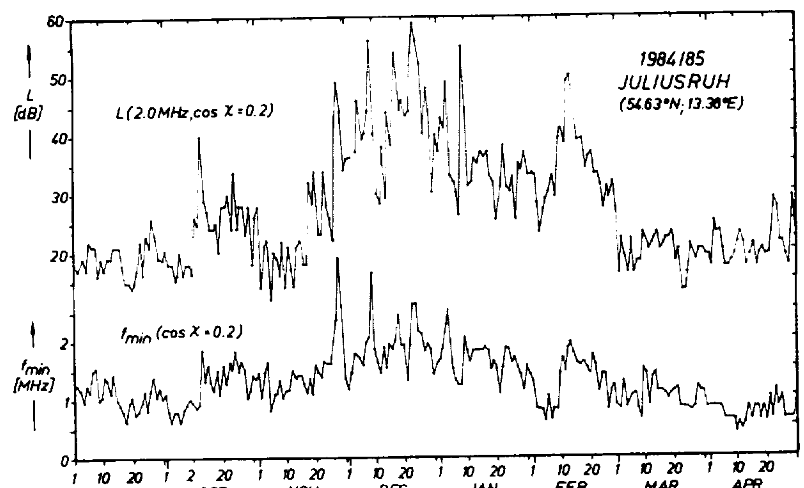
8. **OBSERVED PARAMETERS:** Ionospheric MF -absorption at vertical incidence (A1-method) in dB on 2 MHz, lowest frequency (fmin) in MHz detected by vertical ionosonde measurements, both data are available at constant solar zenith angles (chi = 66.4°, 78.5°, 90°) and at noon conditions, fmin-data since 1987 as hourly values only.

9. **PERIOD OR TIME:** Continuous measurements since 1957 (ionosonde) or 1975 (A1-measurements)

10. **STATION:** Ionosonde Station Juliusruh/Ruegen (54.63° N, 13.38° E)

11. **RESOLUTION AND ACCURACY:** The averaging time to estimate absorption data is normally 10 min, only for noon conditions 60 min. The fmin-values at constant solar zenith angle were derived from adjacent quarter-hourly observations. The accuracy of the absorption data about ± 3 dB, of the fmin-data ±0.1 MHz.

12. **DATA EXAMPLE:** Seasonal variation of ionospheric absorption at 2.0 MHz as well as fmin values at constant solar zenith angle (cos chi=0.2) during the winter half year 1984/85.



13. **DATA FORMAT:** Printed tables, published in HHI Geophys. Data, Berlin.

14. **NOTES:** Details of the A1-method, especially the procedure to estimate representative reference values A_o are described in HHI Geophys. Data, Berlin.

GDR MAP DATA CATALOGUE 5

1. **SUBJECT:** Partial reflection D-region electron density measurement

2. **PRINCIPAL INVESTIGATORS:** Dr.W.Singer, Dr.J.Bremer, D.Keuer, Dr.J.Priese

3. **AFFILIATION:** Heinrich-Hertz-Institute of Atmospheric Research and Geomagnetism, Academy of Sciences of the GDR, Observatory of Atmospheric Research Kuhlungsborn

4. **ADRESS:** Mitschurinstr. 4-6, Kuhlungsborn. DDR-2565, German Democratic Republic

5. **TELEFONE:** 008293 576

6. **TELEX:** 31263 obskb dd

7. **INSTRUMENT:** FM-CW radar at 3.18 MHz, transmitting power 1KW, sweep time 0.6 sec, repetition time 0.8 sec.

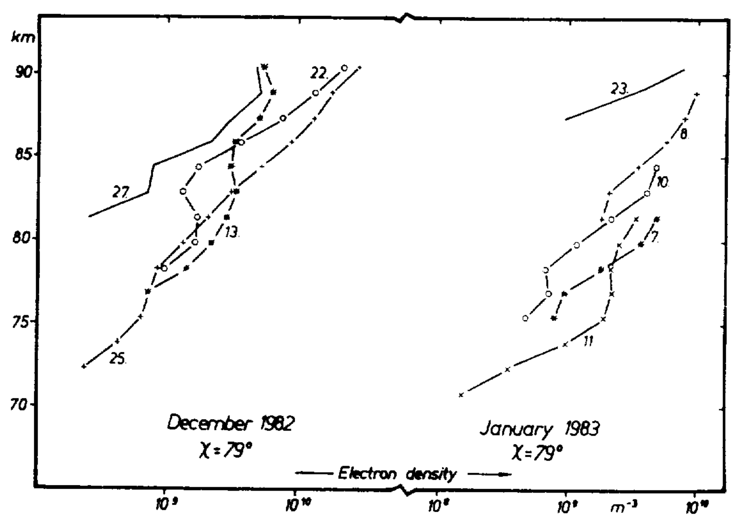
8. **OBSERVED PARAMETERS:** Electron density profiles by means of differential absorption measurements between about 70 and 90 km.

9. **PERIOD OR TIME:** Daytime electron density profiles since December 1982, mainly during winter periods.

10. **STATION:** Ionosonde Station Juliusruh (54.63° N, 13.38° E)

11. **RESOLUTION AND ACCURACY:** Height resolution 1.5 km, time resolution about 5 min.

12. **DATA EXAMPLE:** Typical electron density profiles at constant solar zenith angle during winter 1982/83, the number denote the days in the month.



13. **DATA FORMAT:** Tables or discette (ASCII-CP/M, IBM)

14. **NOTES:** For details see: J.Priese, W.Singer, Measurements of partial reflections at 3.18 MHz using the CW- radar technique: Handbook for MAP 10, 39-44, 1984. W.Singer, J.Priese, P.Hoffmann, Experimental technique of lower ionosphere electron density measurements by means of partial reflections, Adv. Space Res. 8, (4)49-(4)50, 1988.

GDR MAP DATA CATALOGUE 6

1. **SUBJECT:** Partial reflection spaced antenna wind measurement

2. **PRINCIPAL INVESTIGATORS:** Dr.W.Singer, P.Hoffmann, D.Keuer, Dr.J.Priese

3. **AFFILIATION:** Heinrich-Hertz-Institute of Atmospheric Research and Geomagnetism, Academy of Sciences of the GDR, Observatory of Atmospheric Research Kuhlungsborn

4. **ADRESS:** Mitschurinstr. 4-6, Kuhlungsborn. DDR-2565, German Democratic Republic

5. **TELEFONE:** 008293 576 6. **TELEX:** 31263 obskb dd

7. **INSTRUMENT:** FM-CW radar at 3.18 MHz, transmitting power 1KW, sweep time 0.6 sec, repetition time 0.8 sec.

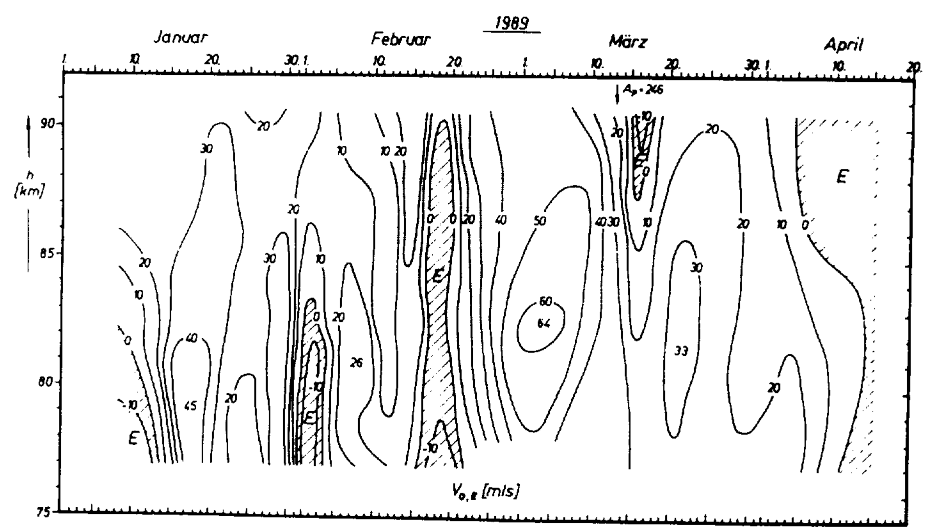
8. **OBSERVED PARAMETERS:** Ionospheric wind profiles between about 70 km and 90 km; echo power and correlation functions of the received complex signals .

9. **PERIOD OR TIME:** First results since summer 1988, more regulary between January and April 1989; all data only during daytime.

10. **STATION:** Ionosonde Station Juliusruh (54.63° N, 13.38° E)

11. **RESOLUTION AND ACCURACY:** Height resolution 1.5 km, time resolution about 5 min.

12. **DATA EXAMPLE:** Typical prevailing zonal wind field during winter 1989



13. **DATA FORMAT:** Tables or discette (ASCII- CP/M, IBM)

14. **NOTES:** For details see: J.Priese, D.Keuer, Experimental technique of a FM-CW radar system for observation of lower ionospere partial reflection drifts, Adv. Space Res.8, (4)51-(4)52, 1988. P.Hoffmann, D. Keuer, W.Singer, Th.Linow, Data processing in a FM-CW-radar system for ionospheric drift measurements, Adv. Space Res. 8, (4)53-(4)54, 1988.

1. SUBJECT: Atmospheric electric potential gradient measured at the surface

2. PRINCIPAL INVESTIGATORS: Pál Bencze, Ferenc Märcz

3. AFFILIATION: Geodetic and Geophysical Research Institute, Hungarian Academy of Sciences

4. ADDRESS: H-9401 Sopron, P.O.Box 5, Hungary

5. TELEPHONE: 36-99-14290 6. TELEX: 249125 MTAGE H

7. INSTRUMENT: Radioactive collector connected to a tube electrometer

8. OBSERVED PARAMETER: gradient of the atmospheric electric field at 1 m height above the surface in an undisturbed environment indicating also changes of the global circuit.

9. PERIOD OF TIME: Continuous recording with a recording speed of 20 mm/h since 1978.

10. STATION: Geophysical Observatory near Nagycenk (47.63^{o}N, 16.72^{o}E, Dip latitude 47.2^{o})

11. RESOLUTION AND ACCURACY: Time resolution: 1 min, accuracy 10 V/m.

12. DATA EXAMPLE: Hourly averages of the atmospheric electric potential gradient in tabular form.

Hour (GMT) day	0	1	2	3	→ 23
1.	60	110	60	70	
2.	100	110	110	90	
3.	160	170	130	130	
4.	+S	+S	+S	+S	
5.	80	40	30	70	
.					
.					
.					

13. DATA FORMAT: Available on discettes for IBM compatible PC-s.

14. NOTES: The recording is continued.

HUNGARIAN MAP DATA CATALOGUE 2

1. SUBJECT: Ionospheric absorption of radio waves measured by oblique incidence (A3 method)

2. PRINCIPAL INVESTIGATORS: Ferenc Märcz, Pál Bencze

3. AFFILIATION: Geodetic and Geophysical Research Institute, Hungarian Academy of Sciences

4. ADDRESS: H-9401 Sopron, P.O.Box 5, Hungary

5. TELEPHONE: 36-99-14290 6. TELEX: 249125 MTAGE H

7. INSTRUMENT: Fixed frequency receiver tuned to the frequency 272 kHz (transmitter: Ceskoslovensko)

8. OBSERVED PARAMETER: Field strength of the reflected wave.

9. PERIOD OF TIME: Ionospheric absorption determined for fixed zenith angles (mainly sunrise, sunset and night absorption) since 1978.

10. STATION: Geophysical Observatory near Nagycenk (47.63°N, 16.72°E, Dip latitude 47.2°)

11. RESOLUTION AND ACCURACY: Time resolution: 1 min, accuracy decreasing with increasing absorption.

12. DATA EXAMPLE: Ionospheric absorption given in tabular form, for sunset (SS) night and sunrise (SR)

Date	SS	night	SR
1/2	31.0	26.6	40.5
2/3	33.2	24.2	44.0
3/4	34.5	27.8	28.5
4/5	36.1	30.1	38.0
5/6	33.2	30.1	x
.			
.			
.			

13. DATA FORMAT: Available on discettes for IBM compatible PC-s.

14. NOTES: The observations are continued.

MAP DATA CATALOGUE

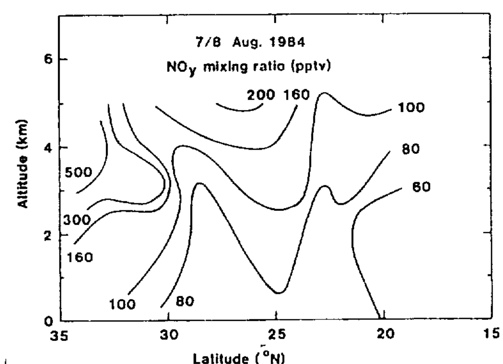
1. SUBJECTS	Aircraft observation of oxides of nitrogen
2. PRINCIPAL INVESTIGATOR(S)	Y.Kondo, I.Iwata, and M.Takagi
3. AFFILIATION	Research Institute of Atmospherics, Nagoya University
4. ADDRESS	Toyokawa, Aichi 442, Japan
5. TELEPHONE	(0)5338-6-3154 (ext) 321
6. TELEX	04322311 RIANAG J
7. INSTRUMENT(S) OR SYSTEM	Chemiluminescent instrument with a ferrous sulfate or a photolytic converter.
8. OBSERVED PARAMETER(S)	NO, NO_y, or NO_2 mixing ratios in the free troposphere. Latitude from 19°N to 43°N was covered.
9. PERIOD OR TIME	From 1983 to 1985. Seasons covered are winter, spring, and summer.
10. STATION	Aircraft

11. RESOLUTION AND ACCURACY

Detection limit for NO and NO_y is about 5 an 15 pptv, respectively.

12. DATA EXAMPLE

Latitudinal distribution of oxides of nitrogen (NO_y) in summer.



13. DATA FORMAT

In tabulated forms.
Raw data are stored on magnetic tape.

14. NOTES

MAP DATA CATALOGUE

1.SUBJECTS	NO balloon observation
2.PRINCIPAL INVESTIGATOR(S)	Y.Kondo, A.Iwata, and M.Takagi
3.AFFILIATION	Research Institute of Atmospherics, Nagoya University
4.ADDRESS	Toyokawa, Aichi 442, Japan
5.TELEPHONE	(0)5338-6-3154(ext)321
6.TELEX	04322311 RIANAG J
7.INSTRUMENT(S) OR SYSTEM	Chemiluminescent NO sonde

8.OBSERVED PARAMETER(S)

NO vertical profiles from 6 to 40 km.
NO mixing ratio at 26 km from sunrise to midday.
NO at 32 km and 40 km at sunrise.
NO at 32 km at sunset.

9.PERIOD OR TIME

September 20, 1983; September 19, 1985; October 4, 1985;
July 29, 1987; September 19, 1987

10.STATION

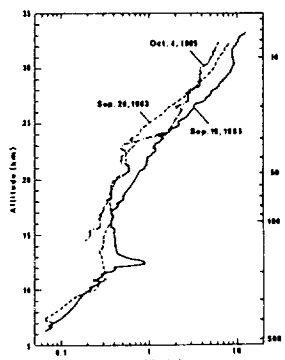
CNES balloon launching center in France (44°N); Uchinoura, Japan (31°N)

11.RESOLUTION AND ACCURACY

Precision:about 10 % in the stratosphere

12.DATA EXAMPLE

Vertical NO profiles obtained on Sep. 20, 1983, Sep. 19, 1985, and Oct. 4, 1985.



13.DATA FORMAT

In tabulated forms
raw data are stored on magnetic tape.

14.NOTES

MAP DATA CATALOGUE

1. SUBJECTS
GC measurements of atmospheric CF_2Cl_2, $CFCl_3$ and N_2O in Antarctica

2. PRINCIPAL INVESTIGATOR(S)
Michio Hirota and Yukio Makino

3. AFFILIATION
Meteorological Research Institute

4. ADDRESS
1-1 Nagamine, Tsukuba, Ibaraki 305, Japan

5. TELEPHONE
0298-51-7111

6. TELEX

7. INSTRUMENT(S) OR SYSTEM

i) Sampling cylinder(stainless-steel cylinder: 300 ml, SS-4HG valves)
ii) Gas-chromatograph(Shimadzu GC-6AM; detector: EDC-4M(ECD))

8. OBSERVED PARAMETER(S)
In the gas-chromatographic analysis, peak areas were used to calculate volume mixing ratios. Latitudinal variations from Tokyo to Syowa Station at intervals of about 5°, time trends at Syowa Station and vertical distributions up to an altitude of 7 km were obtained.

9. PERIOD OR TIME
(i) sea surface air: Nov. & Dec. 1982, 1983, 1984, and Feb. & Mar. 1984.
(ii) surface air at Syowa Station: Feb. 1982-Jan. 1984, and Feb. 1986-Jan. 1987.
(iii) tropospheric air over Syowa Station: Jan., Apr., Oct., and Dec. 1983.

10. STATION
Syowa Station(69.0°S, 39.6°E)

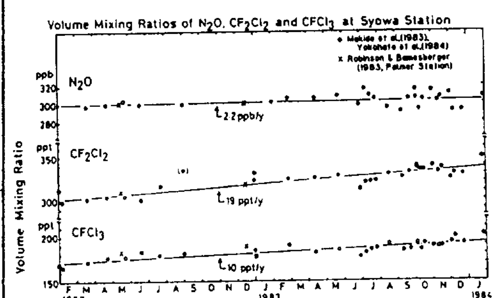
11. RESOLUTION AND ACCURACY

Table 1. Uncertainties in the gas-chromatographic measurement.

Species	CF_2Cl_2	$CFCl_3$	N_2O
Detection limit	15 ppt	4 ppt	10 ppb
Mixing ratio in reference gas	434 ppt	414 ppt	303 ppb
Error in repeated measurements of a reference gas	1.9%	0.6%	2.1%
Error in measurements of several reference gases	2.3%	3.2%	2.9%
Error in repeated measurements for samples	±1.0%	±0.9%	±2.0%

12. DATA EXAMPLE

Time variations of CF_2Cl_2, $CFCl_3$ and N_2O at Syowa Station
——: linear trend



13. DATA FORMAT

14. NOTES
Air samplings between Tokyo and Syowa Station were performed late in 1987.

MAP DATA CATALOGUE

1. SUBJECTS: GC measurements of tropospheric CF_2Cl_2, $CFCl_3$ and N_2O over Japan

2. PRINCIPAL INVESTIGATOR(S): Michio Hirota

3. AFFILIATION: Meteorological Research Institute

4. ADDRESS: 1-1 Nagamine, Tsukuba, Ibaraki 305, Japan

5. TELEPHONE: 0298-51-7111

6. TELEX:

7. INSTRUMENT(S) OR SYSTEM

Air samples were collected on an aircraft by means of an air-pump into stainless-steel cylinders(0.3, 0.5 and 1.0 l). CF_2Cl_2, $CFCl_3$ and N_2O in the sample air were analyzed by GC-ECD methods(Shimadzu GC-6AM).

8. OBSERVED PARAMETER(S)

Mean tropospheric volume mixing ratios of CF_2Cl_2, $CFCl_3$ and N_2O over Japan(34°-38°N) and their time variations were obtained.

9. PERIOD OR TIME

A few flights were performed in each winter season between 1978 and 1986.

10. STATION: Aircraft

11. RESOLUTION AND ACCURACY

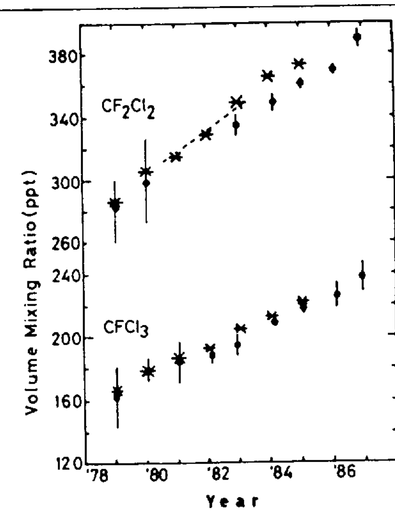
Table 1. Uncertainties in the gas-chromatographic measurement.

Species	CF_2Cl_2	$CFCl_3$	N_2O
Detection limit	15 ppt	4 ppt	10 ppb
Mixing ratio in reference gas	434 ppt	414 ppt	303 ppb
Error in repeated measurements of a reference gas	1.9%	0.6%	2.1%
Error in measurements of several reference gases	2.3%	3.2%	2.9%
Error in repeated measurements for samples	±1.0%	±0.9%	±2.0%

12. DATA EXAMPLE

Mean tropospheric mixing ratios of CF_2Cl_2 and $CFCl_3$

- ⫯ : mean value and standard deviation
- ---: linear trend obtained by continuous measurement at Memanbetsu, Hokkaido (43.9°N)
- ✳ : mean value in Oregon, U. S. A.(45°N) (Rasmussen & Khalil, 1986)



13. DATA FORMAT

14. NOTES

ORIGINAL PAGE IS
OF POOR QUALITY

MAP DATA CATALOGUE

1.SUBJECTS	GC measurements of stratospheric CF_2Cl_2, $CFCl_3$ and N_2O over Japan
2.PRINCIPAL INVESTIGATOR(S)	Hisafumi Muramatsu and Michio Hirota
3.AFFILIATION	Meteorological Research Institute
4.ADDRESS	1-1 Nagamine, Tsukuba, Ibaraki 305, Japan
5.TELEPHONE	0298-51-7111
6.TELEX	

7.INSTRUMENT(S) OR SYSTEM

Stratospheric air samples were obtained using balloon-borne stainless-steel spheres(5 l). The valve of an evacuated sphere was operated using a baroswitch and two cutting heaters. Launching of the sampling system was made only in summer season in order to return the sampling sphere on land.
CF_2Cl_2, $CFCl_3$ and N_2O in the sample air were analyzed by GC-ECD methods(Shimadzu GC-6AM).

8.OBSERVED PARAMETER(S)

Vertical distributions of the stratospheric CF_2Cl_2, $CFCl_3$ and N_2O over Japan(~36°N) in summer season were obtained.

9.PERIOD OR TIME

From 1978 to 1985

10.STATION

Aerological Observatory(36.1°N, 140.1°E)

11.RESOLUTION AND ACCURACY

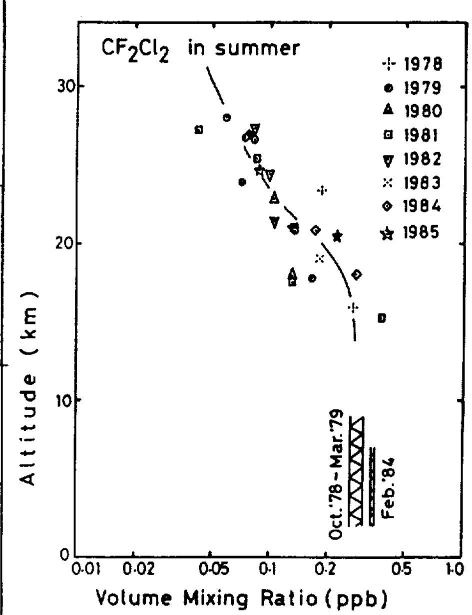
Total error in the measurements of the stratospheric air samples was estimated to be about ±15%.

12.DATA EXAMPLE

Vertical distribution of CF_2Cl_2 in the stratosphere

—: vertical profile calculated from a 1-D model(36°N, summer solstice)

⧖ : range of the tropospheric mixing ratios



13. DATA FORMAT

14.NOTES

MAP DATA CATALOGUE

1.SUBJECTS VHF radar observation

2.PRINCIPAL INVESTIGATOR(S) Tadahiko Ogawa

3.AFFILIATION Communications Research Laboratory (formerly, Radio Research Laboratory)

4.ADDRESS 2-1 Nukui-Kitamachi 4-chome, Koganei-shi, Tokyo 184, Japan

5.TELEPHONE 0423-21-1211 (ext) 363 **6.TELEX** 2832611 DEMPA J

7.INSTRUMENT(S) OR SYSTEM VHF radars (Frequencies: 50 and 112 MHz; Transmitted power: 15 kW peak and 960 W max average; Antenna: coaxial collinear, half-power beam-width of about 4° in the horizontal plane; Beams: two beams with a crossing angle of 33°)

8.OBSERVED PARAMETER(S) (i) Echo power, Doppler spectra, and average Doppler velocities in radio aurora in two line-of-sight directions (auroral radars, 50 and 112 MHz). (ii) Neutral wind velocities in a height range of 80 and 100 km in two line-of-sight directions (meteor radar, 50 MHz).

9.PERIOD OR TIME February 1982 - November 1986.

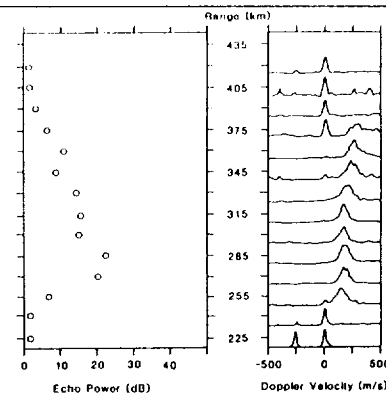
10.STATION Syowa Station, Antarctica (69.01°S, 39.59°E)

11.RESOLUTION AND ACCURACY

Different among individual observations.
(i) Auroral radars; typically, range resolution 15 km, time resolution 7.68 sec, spectral resolution 5.2 Hz. (ii) Meteor radar; range resolution 150 m, accuracy of line-of-sight velocity on the order of 1 m/s.

12.DATA EXAMPLE

Range profiles of echo power and Doppler spectrum in radio aurora observed by the 50 MHz radar (average for 13 sec). Maximum spectral power is normalized to unity. Spectral peaks around 0 m/s are not real.



13.DATA FORMAT

MT; MELCOM 70/25 floating point: 1600 BPI/2400 feet/9 tracks.

14.NOTES (i) The observations will be resumed on February 1989. (ii) The 50 MHz radar is used as an auroral radar or a meteor radar. (iii) Data are not continuous. For period and time for each observation apply to the principal investigator. (iv) Some data of the 50 MHz radar may be released for joint works with the investigator(s) responsible for the individual observations. (v) Brief descriptions of the radar system appears in: Igarashi, K., T. Ogawa, M. Ose, R. Fujii and T. Hirasawa, A new VHF Doppler radar experiment at Syowa Station, Antarctica, Mem. Natl. Inst. Polar Res., Spec. Issue, 22, 258-267, 1982. See the data reports for a part of the radio aurora observations; JARE DATA REPORTS, Nos. 88(1982), 100(1983), 113(1984) and 123(1985), published by the National Institute of Polar Research, Japan.

ORIGINAL PAGE IS
OF POOR QUALITY

MAP DATA CATALOGUE

1. SUBJECT	HF Doppler observation
2. PRINCIPAL INVESTIGATOR(S)	Takashi OKUZAWA and Takashi SHIBATA
3. AFFILIATION	Department of Electronic Engineering, Denki Tsūshin University (DTU)
4. ADDRESS	1-5-1 Chofugaoka, Chofu-shi, Tokyo 182, Japan
5. TELEPHONE	(0)424-83-2161 (ext) 3352 or 3353
6. TELEX	2822-446 UECJ

7. INSTRUMENT(S) OR SYSTEM

The HF Doppler receivers [Frequency: 5 and 8 MHz, JJY-wave signals from Nazaki (36.2° N, 139.9° E)].

8. OBSERVED PARAMETER(S)

Doppler frequency deviations from the above carrier-wave frequencies as a function of time.

9. PERIOD OR TIME

Ionospheric data for the period of January 1982 - May 1985 (at Sugadaira), and since March 1982 (at Chofu). Data of good quality are available only for the daytime because of fade-out at 8 MHz and interference at 5 MHz in the nighttime.

10. STATIONS

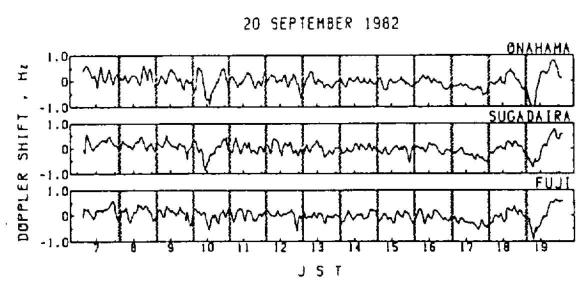
Sugadaira (36.5° N, 138.3° E), Chofu (35.7° N, 139.6° E), (Onahama (36.9° N, 140.9° E), Fuji (35.4° N, 138.6° E))

11. RESOLUTION AND ACCURACY

Different among stations. Frequency and time resolutions are 0.08 Hz (0.2 Hz) and 10 s (33 s) for Sugadaira and Chofu (Onahama and Fuji), respectively, with an accuracy of horizontal trace velocity on the order of 10 ms^{-1} for normal medium-scale traveling ionospheric disturbances.

12. DATA EXAMPLE

Digitized traces of the Doppler variations simultaneously observed at three receiving stations on September 20, 1982; the hatched portion indicates the interpolated periods during data gaps which arise from the scheduled interruption of the JJY transmission from 35 to 39 min every hour.



13. DATA FORMAT

Cassette MT; TEAC DR-55; 8-bit binary expression; Utility for graphical print-out through the EPSON HC-40 micro computer is available at DTU. Partly, MT; SONY 5 inches; Analog recording.

14. NOTES

(i) The observations are continuous. (ii) The observation is continued at Chofu. (iii) Onahama and Fuji stations were operated during the period from September 17 to October 11, 1982. (iV) The data format (for CMT record) is unified in the Japanese community of HFD investigators (the details should be referred to; Tsutsui, M., "Experimental studies on atmospheric and plasma waves in the ionosphere", Ph.D. thesis at Kyoto Univ., June 1983, pp. 35-37).

MAP DATA CATALOGUE

1.SUBJECTS	Mesospheric ozone observation (OHZORA IRA)
2.PRINCIPAL INVESTIGATOR(S)	T.Makino, H.Yamamoto, H.Sekiguchi and I.Naito
3.AFFILIATION	Department of Physics, Rikkyo University
4.ADDRESS	Toshima-ku,Tokyo 171, Japan
5.TELEPHONE	(03) 985-2381, 2671 — 6.TELEX

7.INSTRUMENT(S) OR SYSTEM The infrared atmospheric band radiometer to derive mesospheric ozone density. A 15 μm filter radiometer to get information on satellite attitude and directions of field of views of all sensors.

8.OBSERVED PARAMETER(S)

(1) A PbS array detector (4x5 matrix sensors) output represents the 1.27 μm limb radiance of atmospheric ozone.

(2) A thermistor bolometer detector (2x2 matrix sensors) output gives information on satellite attitude and tangential height.

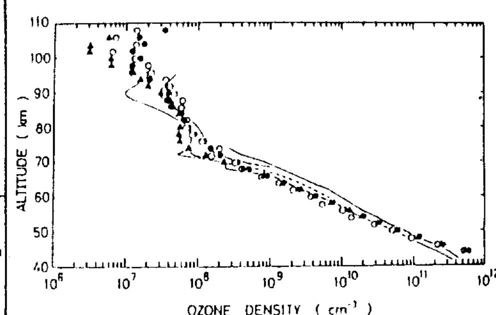
9.PERIOD OR TIME Mesospheric ozone profiles were obtained in the period of February and March 1984 in the latitude region around 50°S to 60°S.

10.STATION On board the satellite OHZORA

11.RESOLUTION AND ACCURACY

Both altitude and spatial resolutions are about 5 km. One limb radiance profile is obtained within 2 minutes.

12.DATA EXAMPLE Ozone profiles obtained at 48°S 157°E(●),at 46°S'36°W(▲) and at 51°S,19°W(○) A rocket data (31°N,131°E;---) are shown together with Krueger-Minzner model(═).



13.DATA FORMAT MT

14.NOTES

H.Yamamoto, T.Makino, H,Sekiguchi and I.Naito
Infrared atmospheric band airglow radiometer on board the satellite OHZORA, J.Geomag.Geoelectr.,40,321,1988

MAP DATA CATALOGUE

1.SUBJECTS OHZORA BUV observation

2.PRINCIPAL INVESTIGATOR(S) Dr.K.Suzuki

3.AFFILIATION Faculty of Education,Yokohama National University

4.ADDRESS Tokiwadai 156,Hodogaya-ku,Yokohama 240,Japan

5.TELEPHONE (0)45-335-1451 (ext)2211 **6.TELEX**

7.INSTRUMENT(S) OR SYSTEM A grating monochromator and a filter photometer.

8.OBSERVED PARAMETER(S) (i) Scanning wavelength range (2500A-3200A). (ii) The optical axis is directed toward anti-solar position(scattering angle=180 degrees). (iii) The field of view is 14°x10°. (iv) The wavelength scanning time is~600ms and the sampling time is 8 or 32s.

9.PERIOD OR TIME Observation was performed between March 1984 and September 1987.

10.STATION On board the satellite OHZORA

11.RESOLUTION AND ACCURACY (i) The wavelength resolution is 6A.
(ii) The field of view at earth surface is 70x100km at SZA of 0° and satellite altitude of 600km.

12.DATA EXAMPLE The raw spectral intensity data are illustrated. The intensities are not correctid by the absolute wavelength sensitivity.

.........Figure.........

13.DATA FORMAT MT: The spectral intensity data and satellite orbital data are edited in FORTRAN format.

14.NOTES (i) Because of the satellite observation schedule the BUV observation is not performed every revolution and day. (ii) The BUV instrument cannot measure the earth albedo during about two weeks in February,April,August and October because of the orbital geometry. (iii) The obervation area is 80°N-80°S. (iv) Ozone profiles (March 1984-October 1986) deduced from present experiment have been published in EXOS-C/ "OHZORA"(1984-15A) Satellite Data Summary of ISAS.

MAP DATA CATALOGUE

1. SUBJECTS Excimer lidar observation

2. PRINCIPAL INVESTIGATOR(S) Prof. Mitsuo Maeda, Dr. Takashi Shibata and Dr. Osamu Uchino

3. AFFILIATION Department of Electrical Engineering, Kyushu University

4. ADDRESS Hakozaki, Higashi-ku, Fukuoka 812, Japan

5. TELEPHONE (0)92-641-1101 (Ex.)5320 **6. TELEX**

7. INSTRUMENT(S) OR SYSTEM Lasers(wavelengths: 290,308,313 and 360 nm for ozone observations, 352 nm for atmospheric density observation, and 340 nm for aerosols), Telescope diameter: 50 cm.

8. OBSERVED PARAMETER(S) (i) Ozone density profile up to 30 km in altitude bu DIAL method. (ii) Atmospheric density profile of the altitude range between 30 and 70 km by Rayleigh back scattering. (iii) El Chichon volcanic cloud back scattering ratio at 340 nm.

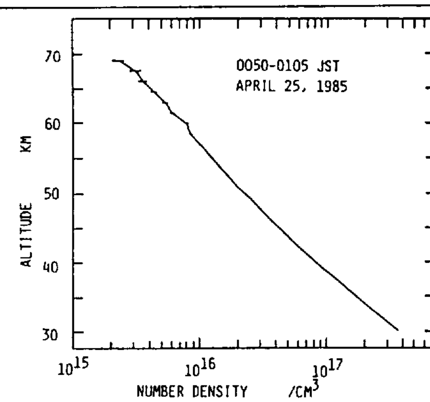
9. PERIOD OR TIME Stratospheric ozone data since 1980. Tropospheric ozone data since August 1985. Atmospheric density data since April 1985. El Chichon cloud between October 1982 and October 1983.

10. STATION Kyushu University (33.6°N, 130.4°E)

11. RESOLUTION AND ACCURACY Minimum vertical (dz) and time (dT) resolutions are 150 m and 2 min. Relative error of ozone at 20 km in altitude is 20 %, when dz=1.5 km and dT=1 hour. Relative error of density at 60 km in altitude is 2 % when dz=1.5 km and dT=15 min.

12. DATA EXAMPLE

Atmospheric density profile obtained between 0050 and 0105 JST, April 25, 1985.



13. DATA FORMAT

Raw data is stored in IBM format 1S floppy diskets.

14. NOTES (i) The observations of ozone and atmospheric density are continuing. (ii) Data is limited to clear weather nights. (iii) Only bad quality data of ozone are available from April 1982 to July 1985 because of the existence of dense stratospheric aerosols from El Chichon volcano. (iv) Details of excimer lidar system should be referred to: Shibata, T., T. Fukuda, T. Narikiyo and M. Maeda, Evaluation of the solar-blind effect in ultravioler ozone lidar with Raman lasers, Applied Optics, Vol. 26, 2604-2608, 1987, and Shibata, T., M. Kobuchi and M. Maeda, Measurements of density and temperature profiles in the middle atmosphere with a XeF lidar, Applied Optics, Vol. 25, 685-688, 1986.

MAP DATA CATALOGUE

1.SUBJECTS Observation of atmospheric minor constituents.

2.PRINCIPAL INVESTIGATOR(S) Professor Tomizo Itoh

3.AFFILIATION The Institute of Space and Astronautical Science

4.ADDRESS 3-1-1 Yoshinodai,Sagamihara-shi, Kanagawa 229, Japan

5.TELEPHONE (0427)-51-3911 (ext.)2515 **6.TELEX** J 27758 ISAS ERO

7.INSTRUMENT(S) OR SYSTEM The balloon-borne grab-sampling system and cryogenic sampling system, and the airplane-borne grab-sampling system. The samples are analyzed for halocarbons, CH_4, CO_2, and carbon and oxygen isotope ratios of CO_2 by gas-chromatography, NDIR and condensation-evaporation method, and mass-spectrometer, respectively, in the laboratory.

8.OBSERVED PARAMETER(S)

(1) Vertical profiles of mixing ratios of CCl_3F, CCl_2F_2, CH_4, and CO_2.

(2) Latitude dependence of mixing ratio of tropospheric CO_2.

(3) Relation between CO_2 mixing ratio and $\delta^{13}C$ value.

(4) Altitude dependence of $\delta^{18}O$ value.

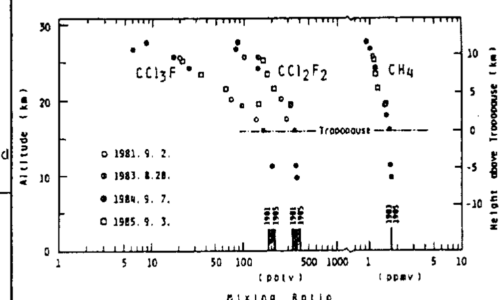
9.PERIOD OR TIME

Balloon; Daytime of 1983.8.28, 1984.9.7, 1985.9.3, and 1986.5.28.
Airplane: Daytime of 1982.10.10, 1983.2.20, 1984.2.14, 1984.8.7, 1984.8.8, and 1985.12.16

10.STATION Sanriku Balloon Center, Yao airport

11.RESOLUTION AND ACCURACY

Height resolution is $\pm$200 m for balloon and $\pm$100 m for airplane.
Accuracy is $\pm$3 pptv for halocarbons, $\pm$8 ppbv for CH_4, $\pm$0.13 ppmv for CO_2 by NDIR, $\pm$3 ppmv for CO_2 by condensation-evaporation method, and $\pm$0.1‰ for $\delta^{13}C$ and $\delta^{18}O$, respectively.



12.DATA EXAMPLE

Observed mixing ratios of halocarbons and methane by balloon grab-sampling (1981, 1983 and 1984) and cryogenic sampling (1985).

13.DATA FORMAT

Discrete digits.

14.NOTES

(1) The observations are continuing.

(2) Some data may be released.

MAP DATA CATALOGUE

1. SUBJECTS
Observation of the stratospheric NO_2 in Antarctica by visible absorption spectroscopy

2. PRINCIPAL INVESTIGATOR(S)
SHIBASAKI Kazuo[1], IWAGAMI Naomoto[2] and OGAWA Toshihiro[2]

3. AFFILIATION
[1]Kokugakuin University ; [2]Geophysics Research Laboratory, University of Tokyo

4. ADDRESS
[1]10-28 Higashi 4-chome,Shibuya-ku,Tokyo 150 ;[2]3-1 Hongo 7-chome,Bunkyo-ku,Tokyo 113, Japan

5. TELEPHONE
[1]3-409-0111 ; [2]3-812-2111

6. TELEX
[2]J33659 UTYOSCI

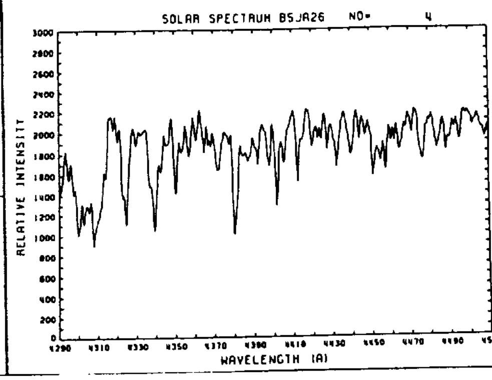
7. INSTRUMENT(S) OR SYSTEM
Monochromator with a sun trucking instrument [NIKON G500II (resolution 0.2nm, f/8.5) for ground-based measurements and Jobin-Yvon H20 (resolution 0.2nm, f/3.5) for balloon-borne measurements].

8. OBSERVED PARAMETER(S)
Solar absorption spectra in visible 428-452 nm region. Slant column density of NO_2 is derived using the least squares fitting method from a whole ratio spectrum taken between an observed and the reference spectra. Vertical column densities are derived from the solar zenith angle dependencies of slant column densities during the morning and evening periods. A vertical profile of the stratospheric NO_2 is retrieved with the constrained linear inversion method.

9. PERIOD OR TIME
(1) Ground-based measurement : March 1983 to January 1984.
(2) Balloon-borne measurement : November 24, 1982, November 12, 1983 and November 20, 1983.

10. STATION
Syowa Station (69.0°S, 39.6°E)

11. RESOLUTION AND ACCURACY
A solar spectral resolution is about 0.2nm. The error in deriving slant column density is less than 10%.
(i)Ground-based measurement: The total uncertainty in derived vertical column density is about $1.5\times10^{15}\,cm^{-2}$ in maximum.
(ii)Balloon-borne measurement: A height resolution is dependent of altitude, ranging from about 1.5km to 5km.



12. DATA EXAMPLE
A raw solar spectrum obtained from the balloon-borne measurement. Abscissa scale is not exactly correct.

13. DATA FORMAT
Raw spectral data : MT[IBM binary expression;Integer, 12 bits A/D data - every about 0.02 nm interval for ground-based observation and about 0.01 nm interval for balloon observation -]

14. NOTES
(i) During 11 months 80 vertical column densities including both morning and evening ones were acquired for ground-based measurements. (ii) Three vertical profiles of the stratospheric NO_2 were derived. (iii) Tables and figures for above results are prepared. (iv) Main results should be referred to 'Shibasaki,K.,N.Iwagami and T.Ogawa,Stratospheric nitrogen dioxide observed by ground-based and balloon-borne techniques at Syowa Station (69.0°S, 39.6°E), Geophys. Res. Lett.,1268, 1986'.

MAP DATA CATALOGUE

1.SUBJECTS Balloon observations of aerosol number density

2.PRINCIPAL INVESTIGATOR(S) M.Takagi, Y.Morita, and A.Iwata

3.AFFILIATION Research Institute of Atmospherics, Nagoya University

4.ADDRESS 3-13 Honohara, Toyokawa, Aichi 442, Japan

5.TELEPHONE 05338-6-3154 (ext)320 **6.TELEX** 4322311 RIANAG J

7.INSTRUMENT(S) OR SYSTEM Light-scattering type aerosol counter

8.OBSERVED PARAMETER(S) Number density of aerosol particles with diameter larger than 0.3 and 0.5 μm, respectively, for the refractive index of 1.40.

9.PERIOD OR TIME Oct. 19, 1982 (Sanriku, 39°N, 142°E)
Aug. 23, 1984 (Xiaghe near Beijing, China, 40°N, 117° E)

10.STATION Balloons; 0-24km alt.(Sanriku) and 0-33km alt.(Xianghe)

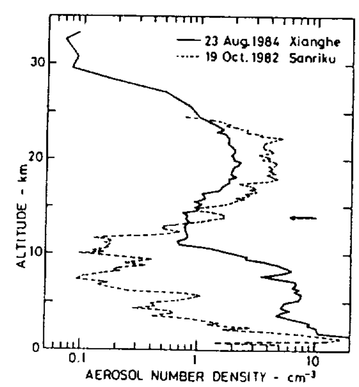
11.RESOLUTION AND ACCURACY

Number density measured;
0.05-50 particles/cm3

Vertical height resolution:
0.5 km (0-24 km alt.)
1 km (24-33 km alt.)

12.DATA EXAMPLE

Vertical profiles of aerosol number density (diameter > 0.3 μm)



13.DATA FORMAT

Primary : Recording chart and floppy disk
Secondary: Figures and tables

14.NOTES

For details of the observations refer to (1)Y.Morita and M.Takagi, Res. Lett. Atmos. Elect., 5, 23 (1985) and (2)M.Takagi et al., Res. Lett. Atmos. Elect., 6, 15 (1986).

MAP DATA CATALOGUE

1.SUBJECTS	Ohzora ALA observation
2.PRINCIPAL INVESTIGATOR(S)	M.Takagi, A.Iwata, and Y.Kondo
3.AFFILIATION	Research Institute of Atmospherics, Nagoya University
4.ADDRESS	3-13 Honohara, Toyokawa, Aichi 442, Japan
5.TELEPHONE	05338-6-3154 (ext)320
6.TELEX	4322311 RIANAG J

7.INSTRUMENT(S) OR SYSTEM

Sun photometer to measure the absorption of sunlight by aerosol (1.0 µm) and ozone (0.6 µm) in the stratosphere

8.OBSERVED PARAMETER(S)

Profiles of extinction coefficients at 1.0 and 0.6 µm.

9.PERIOD OR TIME

March 1984 - December 1986

10.STATION Satellite Ohzora

11.RESOLUTION AND ACCURACY

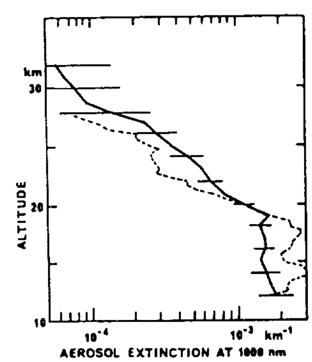
Height resolution; 2 km

Precision: 40% for aerosol(12-30 km alt.)

10% for ozone (30-45 km alt.)

12.DATA EXAMPLE

Aerosol extinction coefficient at 1 µm observed at 20-24°N latitude (full line) and the comparison with lidar back-scatter at Toyokawa 35°N (dotted line).



13.DATA FORMAT

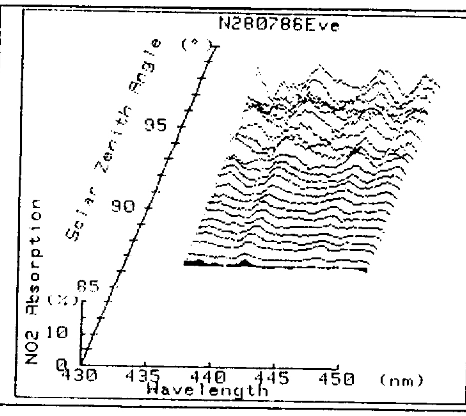
Tables and floppy disk

14.NOTES

For instrumentation and initial results refer to M.Takagi et al., J. Geomag. Geoelectr., 40, 313 (1988)

MAP DATA CATALOGUE

1.SUBJECTS	Atmospheric NO_2 abundance by absorption spectroscopy
2.PRINCIPAL INVESTIGATOR(S)	Professor Buniti Saito, and Mr. Yoshitaka Kiyama
3.AFFILIATION	Niigata Airglow Observatory, Niigata University
4.ADDRESS	Ikarashi-2, Niigata 950-21, Japan
5.TELEPHONE	025-262-6098 (ext) 6150
6.TELEX	
7.INSTRUMENT(S) OR SYSTEM	Czerny-Turner type grating spectrometer: Mirror diameter 50 mm, F number 4.4, Minimum resolution 1.5 A, and Microcomputing system
8.OBSERVED PARAMETER(S)	Spectral intensities of three NO_2 absorption bands, 4352A, 4396A, and 4452A, in two cases, 1) direct solar spectrum, and 2) zenith sky spectrum.
9.PERIOD OR TIME	NO_2 column density data since October 1982.
10.STATION	Niigata Airglow Observatory (37°42' N, 138°49' E)
11.RESOLUTION AND ACCURACY	Resolution of spectrometer: 5A. Accuracy: 5% for observed absorption band intensities.
12.DATA EXAMPLE	Absorption spectra of stratospheric NO_2, July 28, 1986, deduced from the intensity ratios of noon and twilight sky spectra, plotted against solar zenith angle and wavelength.
13.DATA FORMAT	5" disk: bynary format
14.NOTES	The observations are continuing, the fine weather conditions are profitable for the observations. Detailes of observing method are referred to Bulletin of Niigata Airglow Observatory, No.13, p.1, 1985.



MAP DATA CATALOGUE

1.SUBJECTS	Antarctic solar radiation measurement
2.PRINCIPAL INVESTIGATOR(S)	Masataka Shiobara
3.AFFILIATION	Meteorological Research Institute
4.ADDRESS	1-1, Nagamine, Tsukuba, 305 Japan
5.TELEPHONE	(0)298-51-7111 (ext)308
6.TELEX	

7.INSTRUMENT(S) OR SYSTEM

(i) Sunphotometer (Eko, Model MS-111)
(ii) Aureolemeter (Multichannel radiometer with a wide dynamic-range and a narrow FOV)

8.OBSERVED PARAMETER(S)

(i) Spectral optical thickness of aerosols.
(ii) Angular distribution of the aureole intensity in the solar almucantar.
(iii) Degree of polarization of the skylight in the solar principal plane.
(iv) Sky brightness distribution.

9.PERIOD OR TIME January 1984 until January 1985 except for the period of the polar night from May to August.

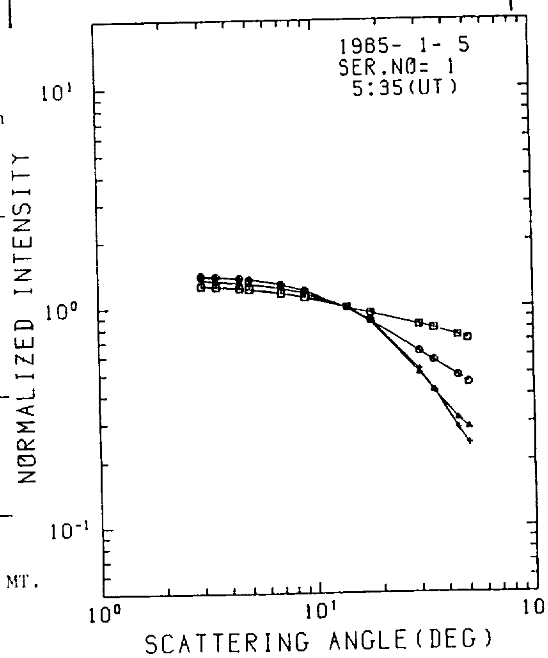
10.STATION Syowa Station, Antarctica (69°00'S, 39°35'E)

11.RESOLUTION AND ACCURACY

(i) Accuracy of the calibration constant (λ=500nm): ~1%
(ii) Accuracy of the degree of polarization (λ=500nm): ~1%
(iii) Angular resolution: 0.05°

12.DATA EXAMPLE

Angular distribution of normalized aureole intensities in the solar almucantar for wavelengths of 369(□), 500(○), 675(△) and 862(+)nm.



13.DATA FORMAT

MT: IBM standard format

14.NOTES

Raw data (radiometer output) are stored on MT.

MAP DATA CATALOGUE

1. SUBJECTS Kyoto meteor radar observation

2. PRINCIPAL INVESTIGATOR(S) Susumu Kato, Toshitaka Tsuda and Mamoru Yamamoto

3. AFFILIATION Radio Atmospheric Science Center (RASC), Kyoto University

4. ADDRESS Uji, Kyoto 611, Japan

5. TELEPHONE (0)774-32-3111 (ext) 3331 **6. TELEX** 5453665 RASCKU J

7. INSTRUMENT(S) OR SYSTEM

Kyoto meteor radar (pulsed Doppler radar) center frequency: 31.57 MHz, bandwidth: 230 kHz, transmitted power: 10 kW peak and 840 W average, duty ratio: 8.4%, transmitting antenna: 5-element Yagi, receiving antenna: two sets of interferometers (three 5-element Yagi pointing eastward and northward).

8. OBSERVED PARAMETER(S)

(1) eastward and northward components of horizontal wind velocity, mean winds, long period oscillations (1.5-20 days), diurnal and semidiurnal tides, gravity waves (2-20 hrs),
(2) meteor echo distribution vs. time and height,
(3) decay time constant of echo power (diffusion coefficient)

9. PERIOD OR TIME Dec. 1977 to present (continuous run from May 1983 to February 1986).

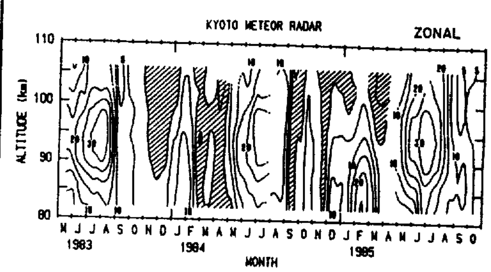
10. STATION Shigaraki MU Observatory (34.85°N, 136.10°E)

11. RESOLUTION AND ACCURACY

Nominal height resolution: 4 km. Time resolution: 2 hr for long period oscillations, shorter for gravity wave observation.

12. DATA EXAMPLE

Eastward mean wind at 80-110 km altitude observed during the MAP period. Shaded area shows westward winds.



13. DATA FORMAT

Time, range, arrival angles, echo power and radial Doppler frequency (stored on 1600 BPI IBM-compatible magnetic tape).

14. NOTES

Participant of ATMAP (Atmospheric Tides Middle Atmosphere Program). Comparison observations of tides and planetary waves with Adelade (35°S, 138°E) and Saskatoon (52°N, 107°W) partial reflection radars.

MAP DATA CATALOGUE

1.SUBJECTS	MU radar observation
2.PRINCIPAL INVESTIGATOR(S)	Professor Susumu Kato, and MUR Group in RASC
3.AFFILIATION	Radio Atmospheric Science Center (RASC), Kyoto University
4.ADDRESS	Uji, Kyoto 611, Japan
5.TELEPHONE	(0)774-32-3111 (ext) 3331 — 6.TELEX 5453665 RASCKU J

7.INSTRUMENT(S) OR SYSTEM

The MU radar (Frequency: 46.5 MHz; Transmitted power; 1,000 kW peak and 50 kW average; Antenna aperture: 8,330 m²).

8.OBSERVED PARAMETER(S)

(i) Doppler power spectra in several line-of-sight directions in the troposphere, the lower stratosphere, and the mesosphere. Radial wind velocity, echo power, and spectral width are deduced by the real-time or off-line function fitting technique. (ii) Echo power and the ACF (auto-correlation function) of the ionospheric incoherent scattering from a height range of 100 to 500 km. (iii) Echo power and the Doppler power spectra of coherent scattering from the field aligned irregularities in the ionospheric E and F regions.

9.PERIOD OR TIME

Tropospheric and stratospheric data since April 1985 (some fragmental data obtained using a partial system available since November 1984). Mesospheric data is available only during daytime. Ionospheric incoherent scatter and coherent scatter data are available since December 1985 and June 1986, respectively.

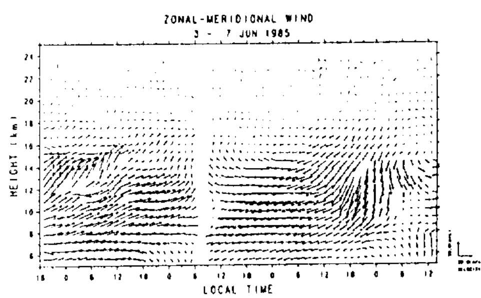
10.STATION Shigaraki MU Observatory (34.85°N, 136.10°E; Dip Latitude 48°)

11.RESOLUTION AND ACCURACY

Different among individual observations. In normal observational mode of the troposphere and stratosphere, time and height resolutions are 2 min and 150 m, respectively, with an accuracy of line-of-sight velocity on the order of 0.15 ms^{-1}.

12.DATA EXAMPLE

Time-height section of horizontal wind velocity observed during June 3–7, 1985. The arrows along x- and y-axes shown beside the figure correspond to the eastward and the northward wind velocities of 30 ms^{-1}, respectively.



13.DATA FORMAT

MT; DEC VAX 11 floating point binary expression; Single precision; Conversion utility to the IBM floating point format available at RASC.

14.NOTES

(i) The observations are continuing. (ii) The data are usually fragmental in units of 12 or 24 hours. The longest period of data covers four days. For period and time of each observation apply to the principal investigator. (iii) Some data may be released for joint work with the investigator(s) responsible for the individual observations. (iv) Details of the MU radar system should be referred to; Fukao, S, T. Sato, T. Tsuda, S. Kato, K. Wakasugi, and T. Makihira, The MU radar with an active phased array system, 1. Antenna and power amplifiers, Radio Science, 20, 1155-1168, 1985, and Fukao, S., T. Sato, T. Tsuda, T. Sato, S. Kato, K. Wakasugi, and T. Makihira, The MU radar with an active phased array system, 2. In-house equipment, Radio Science, 20, 1169-1176, 1985.

MAP DATA CATALOGUE

1.SUBJECTS	HF Doppler observations
2.PRINCIPAL INVESTIGATOR(S)	Dr. Minoru Tsutsui
3.AFFILIATION	Radio Atmospheric Science Center (RASC), Kyoto University.
4.ADDRESS	Gokanosho, Uji, Kyoto 611, Japan
5.TELEPHONE	(0)774-32-3111 ext. 3343
6.TELEX	5453665 RASCKU J

7.INSTRUMENT(S) OR SYSTEM

1. Four channel HF standard radio wave receiver (Frequencies: 2.5, 5, 8, 10MHz, Bandwidth: 10 Hz),
2. Digital data recorder (Cassette tape type),
3. Realtime frequency analyzer and display system.

8.OBSERVED PARAMETER(S)

Doppler frequency deviation of the HF radio waves caused by time change of refractive index in the ionosphere along the ray path of the waves.

9.PERIOD OR TIME

Continuous recording of digital data by 10 second samplings since 1982.

10.STATION

Uji(34.89 N, 135.78 E), Kashiba(34.53 N, 135.67 E), Rokko(34.72 N, 135.23 E).

11.RESOLUTION AND ACCURACY

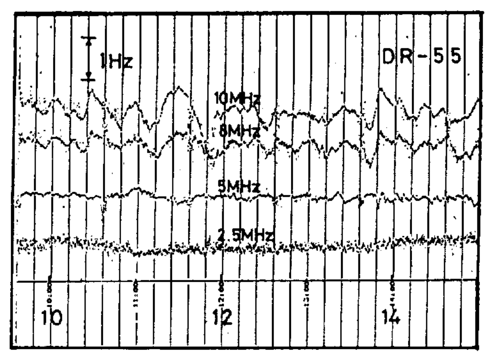
Time resolution : 10 second

Frequency resolution:

0.005	Hz	for	2.5 MHz
0.01	HZ	for	5.0 MHZ
0.016	Hz	for	8.0 MHz
0.02	Hz	for	10.0 MHz

12.DATA EXAMPLE

Doppler frequency deviations versus time (df-t traces)



13.DATA FORMAT

Binary data is recorded in Cassette MT (DR-55 by TEAC Co. Ltd).
Conversion utility to ASCII form which can easily be used on a personal computer is available at RASC.

14.NOTES

Continuous observations at three stations have been conducted since 1982.
Some data may be released for joint works with investigators responsible for the individual observation.

MAP DATA CATALOGUE

1.SUBJECTS Extensive ozone observation

2.PRINCIPAL INVESTIGATOR(S) Shigeru Chubachi

3.AFFILIATION Meteorological Research Institute

4.ADDRESS 1-1 Nagamine, Tsukuba, Ibaraki 305, Japan

5.TELEPHONE 0298-51-7111 (ext) 348 **6.TELEX**

7.INSTRUMENT(S) OR SYSTEM

Dobson spectrophotometer(Beck 122), Dasibi ozone meter(model 1003-AH), Ozonesonde(Type KC-79)

8.OBSERVED PARAMETER(S)

(1) Total ozone observation with sunlight and with moonlight.
(2) Ozonesonde observation.
(3) Umkehr observation.
(4) Surface ozone observation.
(5) Air sampling.

9.PERIOD OR TIME From February 1982 to January 1983

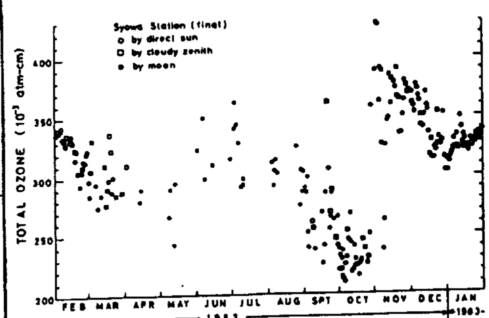
10.STATION Syowa Station, Antarctica(69 00'S,39 35'E)

11.RESOLUTION AND ACCURACY

(1) Total ozone observation with moonlight (within ± 20 matm-cm)
(2) Ozonesonde observation (within ± 10 %)
(3) Surface ozone observation (from +4 to -6 ppbv)
(4) Umkehr observation (± 30 ppbv)

12.DATA EXAMPLE The figure shows the total ozone measurements from February 1982 to January 1983.

Open circles: direct sun measurement, squares: cloudy zenith measurement, and filled circles: direct moon measurement.



13.DATA FORMAT WMO format

14.NOTES The Data are already reported in the "Ozone Data for the World" (Atmospheric Environment Service,Canada)

(Total ozone)	Ozone Data for the World <u>24</u>, 327-328,	<u>25</u>, 376-377
(Ozonesonde)	Ozone Data for the World <u>25</u>, 193-199,	<u>25</u>, 425-429
(Umkehr)	Ozone Data for the World <u>24</u>, 424,	<u>25</u>,413.

MAP DATA CATALOGUE

1.SUBJECTS	Lidar observation of aerosols
2.PRINCIPAL INVESTIGATOR(S)	A.Iwata and M.Takagi
3.AFFILIATION	Research Institute of Atmospherics, Nagoya University
4.ADDRESS	3-13 Honohara, Toyokawa, Aichi 442, Japan
5.TELEPHONE	05338-6-3154 (ext) 323
6.TELEX	4322311 RIANAG J

7.INSTRUMENT(S) OR SYSTEM

Lidar: wavelength: 532 nm — peak power: 0.5 J/pulse

repetition rate: 10 Hz — receiving telescope: 50 cmø

8.OBSERVED PARAMETER(S)

Backscattering ratio in the altitude range 6-44 km.

9.PERIOD OR TIME

Since Dec. 1982.

Observations were made in fair-weather evening hours. Frequency of observations was 10-15 a month in winter and 0-2 a month in summer.

10.STATION

Toyokawa (34.8°N, 137.4°E)

11.RESOLUTION AND ACCURACY

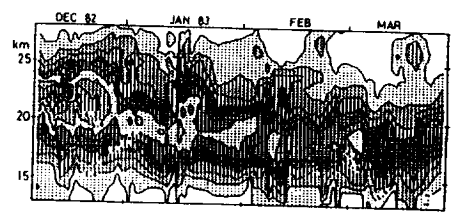
Height resolution: 300 m

Accuracy: 10% (6-30km) for bsr 2

10-30% for bsr 2

12.DATA EXAMPLE

Variation of backscattering ratio during the period from Dec. 1982 to Mar. 1983.



13.DATA FORMAT

MT: ACOS standard character data; Conversion utility to IBM character format available at RIA.

14.NOTES

For details of the system refer to A.Iwata et al., Proc. Res. Inst. Atmospherics, Nagoya Univ., 30, 25-35, 1983.

ORIGINAL PAGE IS
OF POOR QUALITY

MAP DATA CATALOGUE

1.SUBJECTS Aircraft observation of aerosols

2.PRINCIPAL INVESTIGATOR(S) Y.Morita and M.Takagi

3.AFFILIATION Research Institute of Atmospherics, Nagoya University

4.ADDRESS 3-13 Honohara, Toyokawa, Aichi 442, Japan

5.TELEPHONE 05338-6-3154 (ext) 320 **6.TELEX** 4322311 RIANAG J

7.INSTRUMENT(S) OR SYSTEM

1) Light scattering aerosol particle counter
2) Single particle counting condensation nucleus counter

8.OBSERVED PARAMETER(S)

1) Number density of aerosols with diameter larger than 0.3 and 0.5 μm, respectively, for the refractive index of 1.40.
2) Number density of condensation nuclei.

9.PERIOD OR TIME

Dec. 20, 1982; Feb. 18/20, 1983; Feb. 14/16, and Aug. 7/8, 1984; Dec. 16/17, 1985.

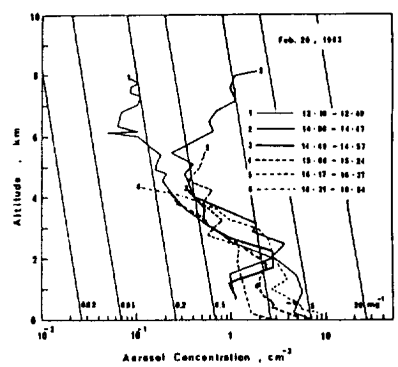
10.STATION Aircraft: 19-43°N, 130-140°E, 0-8 km alt.

11.RESOLUTION AND ACCURACY

Time resolution: 10 sec.
Hight resolution: 100-300 m, different due to observation conditions.

12.DATA EXAMPLE

Vertical profiles of number density of aerosols with diameter larger than o.3 μm on Feb. 20, 1983 at Yao and Akita.



13.DATA FORMAT

Primary: Floppy disk and MT.
Secondary: Tables and figures.

14.NOTES

For details of the observations refer to Y.Morita et al., Res. Lett. Atmos. Elect., 6, 9-14, 1986.

ORIGINAL PAGE IS OF POOR QUALITY

MAP DATA CATALOGUE

1.SUBJECTS	Balloon observations of aerosols in the Antarctica
2.PRINCIPAL INVESTIGATOR(S)	Y.Morita and M.Takagi
3.AFFILIATION	Research Institute of Atmospherics, Nagoya University
4.ADDRESS	3-13 Honohara, Toyokawa, Aichi 442, Japan
5.TELEPHONE	05338-6-3154 (ext) 320
6.TELEX	4322311 RIANAG J

7.INSTRUMENT(S) OR SYSTEM

Light scattering aerosol particle counter.

8.OBSERVED PARAMETER(S)

Number density of aerosols with diameter larger than 0.3 μm and 0.5 μm.

9.PERIOD OR TIME

Apr. 1, Jun. 3, and Oct. 16, 1983; Dec. 18, 1984; Jul. 21, and Oct. 8, 1985.

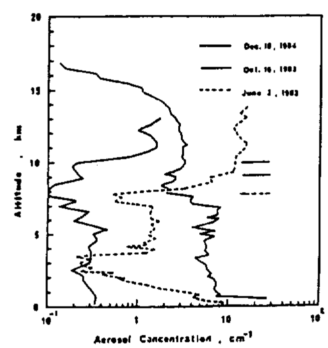
10.STATION Syowa Station, Antarctica.

11.RESOLUTION AND ACCURACY

Height resolutio: about 300 m.

12.DATA EXAMPLE

Vertical profiles of aerosol density with diameter larger than 0.3 μm.



13.DATA FORMAT

Primary: MT and recording chart.
Secondary: Tables and figures.

14.NOTES

For details refer to Y. Morita et al., MAP Handbook 18, 482-485, 1985.

MAP DATA CATALOGUE

1.SUBJECTS	Balloon observation of ion pair production rate in the Antarctica
2.PRINCIPAL INVESTIGATOR(S)	Y. Morita
3.AFFILIATION	Research Institute of Atmospherics, Nagoya University.
4.ADDRESS	3-13 Honohara, Toyokawa, Aichi 442, Japan.
5.TELEPHONE	05338-6-3154 (ext) 320
6.TELEX	4322311 RIANAG J

7.INSTRUMENT(S) OR SYSTEM

Sealed spherical aluminum ionization chamber.
diameter: 39.0 cm, wall thickness: 0.8 mm

8.OBSERVED PARAMETER(S)

Ion pair production rate

9.PERIOD OR TIME

Nov. 24, 1982; Nov. 12 and 20, 1983.

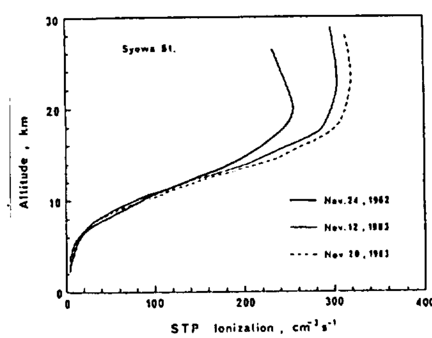
10.STATION Syowa Station, Antarctica.

11.RESOLUTION AND ACCURACY

Height resolution: 300 m (0-29 km alt.)

12.DATA EXAMPLE

Vertical profiles of ion pair production rate, normalized to the standard temperature and pressure.



13.DATA FORMAT

Primary: MT and recording chart.
Secondary: Tables and figures.

14.NOTES

For details refer to Y. Morita, J. Geomag. Geoelectr., 35, 29-38, 1983.

MAP DATA CATALOGUE

1.SUBJECTS	Observations of the molecular forms of stratospheric particles by direct sampling		
2.PRINCIPAL INVESTIGATOR(S)	Prof. Akira Ono and Mr. masahiko Yamato		
3.AFFILIATION	Water Research Institute, Nagoya University		
4.ADDRESS	Furo-cho, Chikusa-ku, Nagoya 464, Japan		
5.TELEPHONE	(0)52-781-5111 (ext)5730	6.TELEX	FAX (0)52-781-3998

7.INSTRUMENT(S) OR SYSTEM

Merlin-IV aircraft, an airborne single stage impactor and a transmission electron microscope in conjunction with the use of the vapor-deposited reagent (calcium, nitron and barium chloride) thin film techniques.

8.OBSERVED PARAMETER(S)

(1) Sizes, concentrations and morphology of particles
(2) Concentrations of sulfate particles, sulfuric acid particles and nitrate particles.
(3) Size distributions of reaction rings of particles collected on calcium thin film
(4) Reactivity and degree of ammonization of sulfate particles

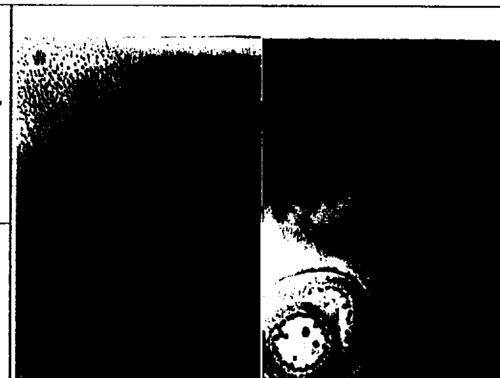
9.PERIOD OR TIME

On 20 Feb., 1983 and on 14 Feb., 1984. Off the coastal region of the Sea of Japan.

10.STATION

11.RESOLUTION AND ACCURACY

Particles down to about 0.1 μm in radius.
Time resolution of the sampling is the flight time, about 7.5 min. on average.



12.DATA EXAMPLE

Electron micrographs of particls collected on inactive thin films (Fig. a) and particles collected on reactive reagent (Ca) thin films (Fig. b).
These particles were sampled at 7.5 km altitude above tvopopause on 14 Feb., 1984.

13.DATA FORMAT

Electron micrographic negatives of particles, which are available at WRI.

14.NOTES

Yamato, M., and A. Ono, Electron Micrographs of Maritime Aerosd Particles. WRI MAP Research Note, Water Research Institute, Nagoya University, 1985
Yamato, M., and A. Ono, Electron Micrographs of Stratospheric Aerosol Partecles. WRI MAP Research Note, Water Research Institute, Nagoya University, 1985

MAP DATA CATALOGUE

1.SUBJECTS	Atmospheric concentrations of halocarbons and methane over Japan
2.PRINCIPAL INVESTIGATOR(S)	Profs. Yoshihiro Makide and Takeshi Tominaga
3.AFFILIATION	Department of Chemistry, Faculty of Science, The University of Tokyo
4.ADDRESS	Hongo, Bunkyo-ku, Tokyo 113, Japan
5.TELEPHONE	(0)3-812-2111 (ext) 4347 — 6.TELEX: UTYOSCI J33659

7.INSTRUMENT(S) OR SYSTEM Sampling of ambient air into preevacuated all-metal sample flasks (0.5-30 liter volume) on the ground, by airplane, or by balloon. Collected samples are analyzed at The University of Tokyo by gaschromatography with ECD (for halocarbons) and FID (for methane).

8.OBSERVED PARAMETER(S) Atmospheric concentrations (volume mixing ratios) of CCl_2F_2, CCl_3F, CCl_2FCClF_2, CH_3CCl_3, CCl_4, $CHCl{=}CCl_2$, $CCl_2{=}CCl_2$, and CH_4. 1) Trend in background concentrations in the mid-latitude Northern Hemisphere (observation in Hokkaido). 2) Vertical distribution in the stratosphere and troposphere by balloon-borne grab- and cryogenic-sampling. 3) Distribution and behavior in the troposphere and around the tropopause by aircraft sampling. 4) Estimation of emission of these compounds by human activities.

9.PERIOD OR TIME 1) Background concentration measurement every summer and winter from 1979 to date. 2) Balloon sampling in summers from 1981 to 1984 by grab-sampling, and from 1985 to date by cryogenic-sampling. 3) Aircraft sampling several times in the MAP period.

10.STATION

11.RESOLUTION AND ACCURACY Determination of Atmospheric concentration with precision of about ±1% for halocarbons at pptv ($=10^{-12}$ v/v) concentration level, and ±0.5% for methane at ppmv ($=10^{-6}$ v/v) concentration level.

12.DATA EXAMPLE Temperature programmed ECD gaschromatogram of a background atmospheric sample (15 ml STP). Each halocarbon concentration (of 0.1-- 500 pptv) is determined by data processor based on the peak area.

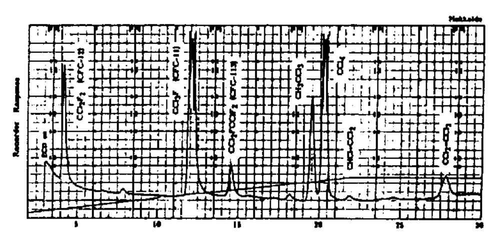


Fig. Typical ECD gaschromatogram of atmospheric halocarbons observed in the mid-latitude Northern Hemisphere. Sample: collected at Nosappu-misaki Point, Hokkaido (43.4°N, 145.8°E) on January 31, 1988. Sample size: 15 ml STP. Separation column: Silicone OV-101 (temperature programed from -40 to 70°C).

13.DATA FORMAT

14.NOTES

Background concentrations of halocarbons and methane in the Southern Hemisphere have been measured by analyzing the samples collected in Antarctica near Syowa Station since 1982.

MAP DATA CATALOGUE

1.SUBJECTS Atmospheric concentrations of halocarbons and methane in Antarctica

2.PRINCIPAL INVESTIGATOR(S) Profs. Yoshihiro Makide and Takeshi Tominaga

3.AFFILIATION Department of Chemistry, Faculty of Science, The University of Tokyo

4.ADDRESS Hongo, Bunkyo-ku, Tokyo 113, Japan

5.TELEPHONE (0)3-812-2111 (ext)4347 **6.TELEX** UTYOSCI J33659

7.INSTRUMENT(S) OR SYSTEM Grab-sampling of ambient air into preevacuated all-metal sample flasks (2-8 liter volume) on the ground near Syowa Station. Collected samples are analyzed in Japan (at The University of Tokyo) by gaschromatography with ECD (for halocarbons) and FID (for methane).

8.OBSERVED PARAMETER(S)

The distribution and trend in atmospheric concentrations of CCl_2F_2, CCl_3F, CCl_2FCClF_2, CH_3CCl_3, CCl_4, $CHCl{=}CCl_2$, $CCl_2{=}CCl_2$, and CH_4.

9.PERIOD OR TIME

Preliminary measurement in 1981, then systematically since 1982. Mainly in January-February, and several times in other seasons.

10.STATION Syowa Station, Antarctica

11.RESOLUTION AND ACCURACY Determination of Atmospheric concentration with precision of about ±1% for halocarbons at pptv ($=10^{-12}$ v/v) concentration level, and ±0.5% for methane at ppmv ($=10^{-6}$ v/v) concentration level.

12.DATA EXAMPLE Temperature programmed ECD gaschromatogram of an Antarctic atmospheric sample (15 ml STP). Each halocarbon concentration (of 1-500 pptv) is determined by data processor based on the peak area.

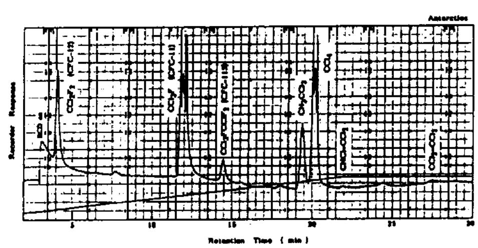


Fig. Typical ECD gaschromatogram of atmospheric halocarbons observed in Antarctica. Sample: collected at 500m NE of Syowa Station, Antarctica (69.0°S, 39.6°E) on December 15, 1986. Sample size: 15 ml STP. Separation column: Silicone OV-101 (-40 to 70°C).

13.DATA FORMAT

14.NOTES More systematic measurements of atmospheric concentrations of halocarbons and methane have been done in the Northern Hemisphere around Japan: 1) trend of background concentrations (observation at Hokkaido every summer and winter since 1979), 2) vertical distribution in the stratosphere by balloon-borne grab- and cryogenic-sampling, 3) distribution and behavior in the troposphere and around the tropopause by airplane grab-sampling, 4) measurement of emission by human activity, etc.

and troposphere

MAP DATA CATALOGUE

1.SUBJECTS RASS(Radio Acoustic Sounding System) experiment

2.PRINCIPAL INVESTIGATOR(S) N. Matuura, Y. Masuda, K. Takahashi, H. Inuki

3.AFFILIATION Communications Research Laboratory, Ministry of Posts and Telecommunications

4.ADDRESS Koganei-shi, Tokyo 184, Japan

5.TELEPHONE (0)423-21-1211 **6.TELEX** 2832611 DEMPA J

7.INSTRUMENT(S) OR SYSTEM

Radio System: MU Doppler radar (Freq. 46.5MHz, peak power 1MW, antenna gain 33dB).
Acoustic System: Pneumatic acoustic generator (Freq. 75-105Hz, acoustic power 300W, acoustic antenna gain 11dB).

8.OBSERVED PARAMETER(S)

1) Doppler power spectra of backscattered echoes in two kinds; one is the RASS echo from the atmospheric perturbation imposed by an artificially generated acoustic wave and the other is the echo from the atmospheric turbulence of natural origin.
2) Temperature profiles in the troposphere and stratosphere reduced from the data of speed of sound versus altitude.

9.PERIOD OR TIME

Data were obtained fragmentarily for the periods; March 1985, August 1985, January 1986, July 1986, December 1986 and August 1987.

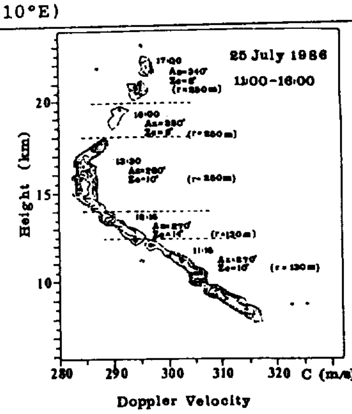
10.STATION Shigaraki MU Observatory (34.85°N, 136.10°E)

11.RESOLUTION AND ACCURACY

Temperature profiles were obtained with a height resolution of 150 m and with an accuracy of 1 °C.

12.DATA EXAMPLE

Contours of RASS echo power spectra in the coordinates of height versus Doppler velocity in line-of-sight direction (which gives an approximate sound speed and hence temperature).



13.DATA FORMAT

MT : DEC VAX 11 floating point binary expression, single precision.

14.NOTES

Observations are fragmentary. More details of the RASS experiment should be referred to: N. Matuura et al., Radio acoustic measurement of temperature profile in the troposphere and stratosphere, Nature 323, 426-428, October 1986, Y. Masuda Influence of wind and temperature on the height limit of a radio acoustic sounding system (RASS), Radio Sci., In press 1988, and T. Tsuda et al., High time resolution monitoring of tropospheric temperature with a radio acoustic sounding system (RASS), Pure Appl. Geophys.,In press 1988.

ORIGINAL PAGE IS OF POOR QUALITY

MAP DATA CATALOGUE

1.SUBJECTS Balloon observation of stratospheric gravity waves and turbulence

2.PRINCIPAL INVESTIGATOR(S) Hiroshi Tanaka and Manabu D. Yamanaka

3.AFFILIATION Water Research Institute, Nagoya University

4.ADDRESS Chikusa-ku, Nagoya 464, Japan

5.TELEPHONE (0)52 781 5111 ext 5733 **6.TELEX**

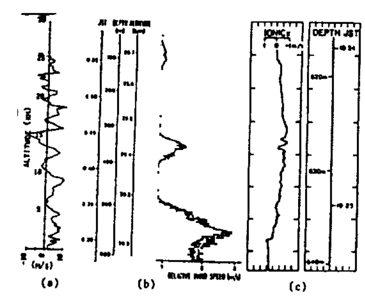
7.INSTRUMENT(S) OR SYSTEM (i) Adapted Gill-type propeller anemometer. (ii) Glow-discharge ionic anemometer. (iii) Scientific balloon facilities and equipment of the Institute of Space and Astronautical Science(ISAS): B5-type zero-pressure balloon(5000m^3, 22.6m diameter), pressure gauge, ascent meter, altitude sensor and reel-up/down winch(max 3km).

8.OBSERVED PARAMETER(S) Horizontal velocities obtained by balloon tracking (vertical profile from surface to the ceiling level). Horizontal velocities relative to balloon motion obtained by the propeller anemometer and ionic anemometer(vertical profiles the scanning winch). Relative wind azimuth obtained by the gondola attitude. Pressure of the flight level. Balloon ascent velocity.

9.PERIOD OR TIME (i) 2202UT 19 September 1982 to 0500UT 21 September 1982. (ii) 2232 UT 25 September 1983 to 1312UT 26 September 1983. (iii) 2222UT 16 May 1984 to 0130UT 18 May 1984. (iv) 2220UT 7 September 1984 to 1340UT 8 September 1984.

10.STATION Within 600km from the Sanriku Balloon Center, ISAS(39 09 30N, 141 49 30E)

11.RESOLUTION AND ACCURACY Accuracy of wind velocity of the propeller anemometer is 0.9m/s and that of the ionic anemometer is 0.005m/s at 25km altitude. Accuracies of range and angles of balloon tracking are 100m and 0.1 degree, respectively. Accuracies of the pressure gauge and ascent meter are 0.1hPa and 0.0001hPa/20s, respectively.



12.DATA EXAMPLE Vertical profiles of (a) meridional wind velocity by balloon tracking, (b) relative wind velocity by the propeller anemometer, and (c) relative wind velocity by the ionic anemometer are shown in the figure. Hierarchical structure like 'gravity waves', 'gust layers' and 'billow turbulence' are typically detected.

13.DATA FORMAT (i) Tracking data (JST, range, azimuth, elevation, distance, altitude, latitude, and longitude) are on teletype prints, (ii) PCM-FM data of the balloon-borne sensors(propeller anemometer, ionic anemometer, pressure gauge, ascent meter, winch rotation counter, attitude sensor and other housekeeping monitors) are in analogue MT's.

14.NOTES Information about the data can be addressed to M.D.Yamanaka, Institute of Earth Science, Faculty of Education, Yamaguchi University, Yamaguchi-shi, Yamaguchi 753, Japan.
Details of sensors and balloon equipment can be referred to Yamanaka et al., J. Atmos. Ocean. Tech., 2, 472-481, 1985; Yamanaka et al., Rev. Sci. Instrum., 56, 617-622, 1985; Matsuzaka et al., Adv. Space Res., 5(1), 41-44, 1985.
Some quick reports of the data are published in Yamanaka and Tanaka, J. Meteor. Soc. Japan, 62, 177-182, 1984; Yamanaka et al., J. Meteor. Soc. Japan, 63, 483-489, 1985.

MAP DATA CATALOGUE

1.SUBJECTS	Meteorological rocket observation
2.PRINCIPAL INVESTIGATOR(S)	Hiroshi Kanzawa and Sadao Kawaguchi
3.AFFILIATION	National Institute of Polar Research
4.ADDRESS	1-9-10 Kaga, Itabashi-ku, Tokyo 173, Japan
5.TELEPHONE	(0)3-962-4711
6.TELEX	2723515 POLRSC J

7.INSTRUMENT(S) OR SYSTEM

Meteorological Rocketsonde (ES64CP-Echosonde, Transmitted Frequency: 1687 MHz), Radar (Transmitted Frequency: 1673 MHz), Rocket (MT-135JA Rocket).

8.OBSERVED PARAMETER(S)

Temperature and winds (eastward and northward) in the altitude region between 20 km and 60 km.

9.PERIOD OR TIME

11 launches were performed in 1985 as a project of 26th Japanese Antarctic Research Expedition. Time (UT) and date of the rocket launches are as follows. 1400 on 30 Jan.; 1430 on 26 Mar.; 1335, 1616, 1810, 2002, 2158 on 28 Jun.; 1400, 1600, 1800, 2000 on 25 Sep.

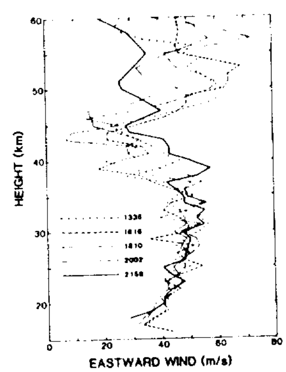
10.STATION Syowa Station (69°00'S, 39°35'E), Antarctica

11.RESOLUTION AND ACCURACY

Height resolution is 1 km. Wind errors are about 1 m/s at the 20 km level and a few m/s at the 60 km level. Temperature errors are within 1K at the 20 km level and a few K at the 60 km level.

12.DATA EXAMPLE

Five vertical profiles of eastward wind velocity on 28 June 1985 (Time is in UT).



13.DATA FORMAT

Data will be published in tables and figures as a volume of the JARE DATA REPORTS series (in preparation).

14.NOTES

Characteristic of this rocket observation is successive launches at intervals of about 2 hours for detecting internal gravity waves. 5 launches on 28 June and 4 launches on 25 September. Details of the experiments should be referred to Kanzawa, H., Y. Ito, H. Itakura, S. Fukusawa, H. Yamagishi and S. Kawaguchi (1986): Report on the MT-135JA Meteorological Rocket Experiment (JARE-26), Antarctic Record (Nankyoku Shiryo), 30, 219-245 (in Japanese with English abstract).

MAP DATA CATALOGUE

1.SUBJECTS NOAA satellite observation

2.PRINCIPAL INVESTIGATOR(S) Takashi Yamanouchi

3.AFFILIATION National Institute of Polar Research

4.ADDRESS 1-9-10 Kaga, Itabashi-ku, Tokyo 173, Japan

5.TELEPHONE (0)3-962-4711 (ext) 451 **6.TELEX** 2723515 POLRSC J

7.INSTRUMENT(S) OR SYSTEM

TIROS-N/NOAA series satellites – HRPT data – TOVS-HIRS/2: 20 channels infrared sounder, SSU: infrared stratospheric sounder MSU: microwave sounder; AVHRR: high resolution (1 km) visible and infrared images (4 or 5 channels)

8.OBSERVED PARAMETER(S)

Visible and infrared radiance from which several parameters can be retrieved.

1) Total ozone amount
2) Water vapor profile
3) Temperature profile
4) Cloud and sea ice distributions

9.PERIOD OR TIME

January 1982-March 1984 }
December 1984-January 1988 } one orbit per day

10.STATION Receiving station: Syowa Station (69°00'S, 39°35'E), Antarctica

11.RESOLUTION AND ACCURACY

HIRS/2: 17-45 km

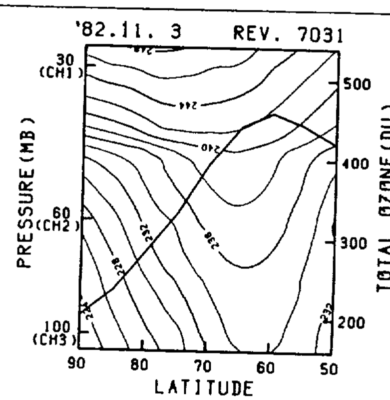
AVHRR: 1.1 km (at nadir)

....

Total ozone: $\pm$13DU (10^{-3}atm-cm)

12.DATA EXAMPLE

Latitudinal variations of vertical temperature distribution (channel brightness temperature) and total ozone amount obtained by NOAA-7 (thick line) in November 1982.



13.DATA FORMAT

Original HRPT data: high density digital tape (7 track, 1/2", 9200 ft). Conversion utility to CCT available at NIPR. Ozone data tape: CCT.

14.NOTES

Receiving of NOAA HRPT data is continuing. Ozone data have been retrieved only for 1981 and 1982.

MAP DATA CATALOGUE

1.SUBJECTS OBSERVATION OF INFRASONIC WAVES

2.PRINCIPAL INVESTIGATOR(S) Prof. Makoto Tahira

3.AFFILIATION Department of Earth Sciences, Aichi University of Education

4.ADDRESS Kariya, 448 JAPAN

5.TELEPHONE 0566-36-3111 **6.TELEX**

7.INSTRUMENT(S) OR SYSTEM

A tripartite array of infrasonic microphones and real time signal analyzer.

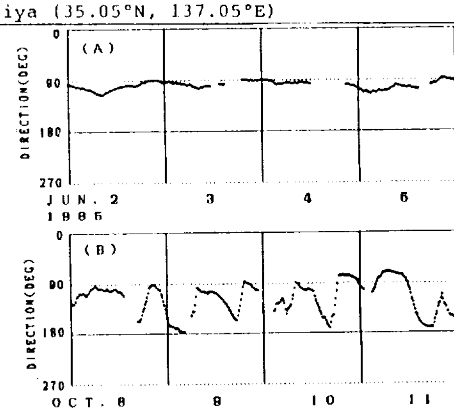
8.OBSERVED PARAMETER(S) (i) Infrasonic waves generated by the ocean waves in stormy regions (microbaroms); Maximum correlation, direction of arrival, horizontal phase velocity, RMS amplitude, and dominant frequency. (ii) Infrasonic waves from Sakurajima Volcano; direction of arrival, horizontal phase velocity, peak amplitude, and travel time.

9.PERIOD OR TIME Microbaroms data: from May 1984 to August 1987 (with drop out for several months). Volcanic signals have been recorded since April 1984 (observation continued).

10.STATION Aichi University of Education, Kariya (35.05°N, 137.05°E)

11.RESOLUTION AND ACCURACY

Time resolution is 15 min for microbaroms. Accuracy is 2° for direction of arrival and 20 m/sec for horizontal phase velocity.



12.DATA EXAMPLE Plots of the direction of arrival of microbaroms against time are shown for the signals reflected at upper stratosphere(A) and at lower thermosphere(B). The semi-diurnal variation observed in the latter plots is an indication of the phase of semi-diurnal atmospheric tides at 110 km level.

13.DATA FORMAT Both microbaroms data and volcanic signals data are saved on 1 MB floppy disks for a personal computer (NEC,PC-9801). The original analogue data of the volcanic signals are also recorded on FM magnetic tapes (SONY FC-14).

14.NOTES (i) Observation of microbaroms is often blocked by wind noises especially in the daytime and in winter and spring seasons. (ii) Description of the system is given in M.Tahira(1988), J.Meteor.Soc.Jpn.,66,17-26, and in M.Tahira(1985), Bull.Aichi Univ.Education,34,143-153 (in Japanese).

MAP DATA CATALOGUE

1. SUBJECTS

Observations of the molecular forms of stratospheric particles by direct sampling

2. PRINCIPAL INVESTIGATOR(S)

Prof. Akira Ono and Mr. Masahiko Yamato

3. AFFILIATION

Water Research Institute, Nagoya University

4. ADDRESS

Furo-cho, Chikusa-ku, Nagoya 464, Japan

5. TELEPHONE

(0)52-781-5111 (ext)5730

6. TELEX

FAX (0)52-781-3998

7. INSTRUMENT(S) OR SYSTEM

Merlin-IV aircraft, an airborne single stage impactor and a transmission electron microscope in conjunction with the use of the vapor-deposited reagent (calcium, nitron and barium chloride) thin film techniques.

8. OBSERVED PARAMETER(S)

(1) Sizes, concentrations and morphology of particles

(2) Concentrations of sulfate particles, sulfuric acid particles and nitrate particles.

(3) Size distributions of reaction rings of particles collected on calcium thin film

(4) Acidity and degree of ammonization of sulfate particles

9. PERIOD OR TIME

(1) February 20, 1983

(2) February 14, 1984

10. STATION

11. RESOLUTION AND ACCURACY

Particles down to about 0.1 μm in radius. Time resolution of the sampling is about 7.5 min. on average.

..........Figure..........

Fig. a

Fig. b

12. DATA EXAMPLE

Electron micrographs of particles collected on inactive thin films (Fig. a) and particles collected on reactive reagent (Ca) thin films (Fig. b). These particles were sampled at 7.5 km altitude above tropopause on 14 Feb. 1984.

13. DATA FORMAT

Electron micrographic negatives of particles, which are available at WRI.

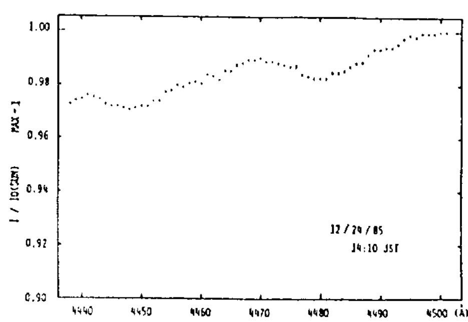
14. NOTES

Yamato, M., and A. Ono, Electron Micrographs of Maritime Aerosol Particles. WRI MAP Research Note, Water Research Institute, Nagoya University, 1985

Yamato, M., and A. Ono, Electron Micrographs of Stratospheric Aerosol Particles. WRI MAP Research Note, Water Research Institute, Nagoya University, 1985

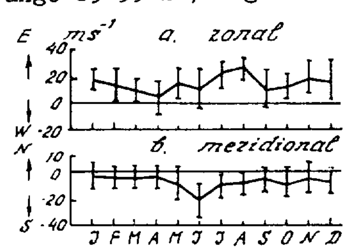
MAP DATA CATALOGUE

1.SUBJECTS	Spectroscopic measurements of minor constituents
2.PRINCIPAL INVESTIGATOR(S)	Takashi Watanabe and Masatoshi Nakamura
3.AFFILIATION	Institute of Physics, University of Tsukuba
4.ADDRESS	Sakura, Ibaraki 305, Japan
5.TELEPHONE	(0)298-53-4537 or 4010
6.TELEX	
7.INSTRUMENT(S) OR SYSTEM	Double monochromator with 30-cm coudé telescope
8.OBSERVED PARAMETER(S)	Absorption spectra of tropospheric and stratospheric NO_2 in visible region using either sun or moon as a light source.
9.PERIOD OR TIME	December 1984 to October 1986. Data are available only for cloudless days. Nighttime data are available since August 1985.
10.STATION	University of Tsukuba (140.106°E, 36.105°N)
11.RESOLUTION AND ACCURACY	Wavelength range: 443B-4501Å, 1Å interval. Resolution: 4.2Å. Time interval: 5 to 10 minutes.
12.DATA EXAMPLE	NO_2 absorption spectrum versus wavelength.
13.DATA FORMAT	(i) Raw absorption data: 5 inch floppy disk (OS: Apple DOS 3.3) (ii) NO_2 vertical column density versus time (JST)
14.NOTES	



SOVIET MAP DATA CATALOGUE

1. SUBJECTS: LF ionospheric drift measurements
2. PRINCIPAL INVESTIGATORS: Edward S.Kazimirovsky, Victor D. Kokourov and Venedict F.Petruchin
3. AFFILIATION: Siberian Institute of Terrestrial Magnetism, Ionosphere and Radio Propagation, Siberian Department, USSR Academy of Sciences
4. ADDRESS: 664033 Post Box 4, Irkutsk, USSR
5. TELEPHONE: (395)46-05-20   6. TELEX:
7. INSTRUMENTS OR SYSTEM: 3 spaced receivers, loop aerials, frequency: 200 kHz, the distance from broadcasting transmitter ~ 150 km, the distance between receivers   500 m.
8. OBSERVED PARAMETERS: night-time half-hourly eastward and northward components of horizontal wind velocity, mean winds, long-period oscillations (2-30 days), semidiurnal tides, gravity waves (30-200 min).
9. PERIOD OF TIME: August 1974 to present (continuous run from January 1981)
10. STATION: Badary Observatory, 52°N, 102°E
11. RESOLUTION AND ACCURACY: Height range 85-95 km, night-time measurements from sunset to sunrise. Time resolution 0.5 hr for standard processing, shorter for gravity wave observations, 1 day for long period oscillations.



12. DATA EXAMPLE: Mean annual variations of zonal (a) and meridional (b) prevailing winds observed during 1975-1985. Vertical segments show standard deviations.
13. DATA FORMAT: Date, time, velocity, azimuth, zonal component, meridional component - in tabular form.
14. NOTES: Participant of DYNAMICS, ATMAP, MAP/WINE Middle Atmosphere Program. Comparison observations with Collm (52°N, 15°E) and Saskatoon (52°N, 107°W). Investigation of prevailing wind dependence on the stratospheric warmings.

USSR MAP DATA CATALOGUE 1

1.SUBJECT: Rocket measurements of nitric oxide

2.PRINCIPAL INVESTIGATOR(S): Dr. G.A.Tuchkov
Dr. A.M.Zadorozhny

3.AFFILIATION: Division for Atmospheric Research, Novosibirsk State University

4.ADDRESS: Novosibirsk 630090, USSR

5.TELEPHONE:

6. TELEX:

7.INSTRUMENT(S) OR SYSTEM: The rocket-borne Gerdien condenser with the selectively ionizing NO Krypton discharge lamp.

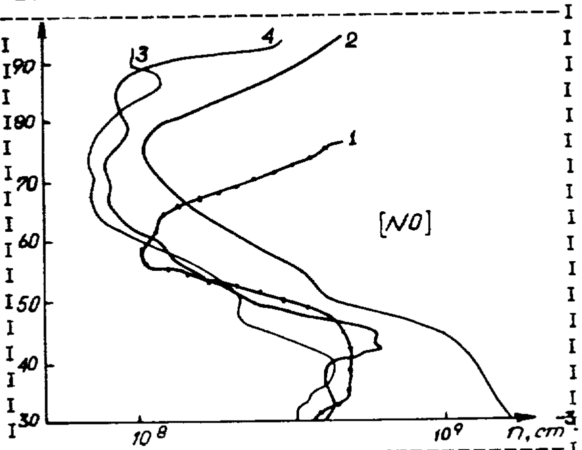
8.OBSERVED PARAMETER(S): Nitric oxide altitude distribution at altitudes from about 30 to 90 km.

9.PERIOD OR TIME:
1) December 8, 1985 10:40 LT; 2) December 8, 1985 11:50 LT;
3) December 14, 1985 14:40 LT; 4) December 14, 1985 15:40 LT;
5) March 24, 1987 02:25 LT; 6) March 28, 1987 17:45 LT.

10.STATION: Middle latitudes of USSR

11.RESOLUTION AND ACCURACY: Vertical resolution <0.5 km. Error about 85%.

12.DATA EXAMPLE: Vertical profiles of nitric oxide obtained in December, 1985.



13.DATA FORMAT:

14.NOTES: Tuchkov G.A., Zadorozhny A.M. In-situ measurements of the nitric oxide altitude distribution in the middle atmosphere. - Kosmicheskie Issledovaniya, 1988, Vol. 26, No. 3, p. 500-503.

USSR MAP DATA CATALOGUE 2

1. SUBJECT: Rocket measurements of aerosol

2. PRINCIPAL INVESTIGATOR(S): Dr. O.A.Bragin
Dr. T.I.Orishich

3. AFFILIATION: Division for Atmospheric Research, Novosibirsk State University

4. ADDRESS: Novosibirsk 630090, USSR

5. TELEPHONE: 6. TELEX:

7. INSTRUMENT(S) OR SYSTEM: The photo-electric counter of aerosol with antijamming system.

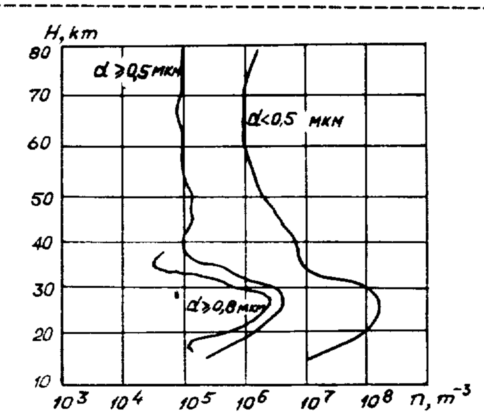
8. OBSERVED PARAMETER(S): The altitude distribution of aerosol in three size ranges at heights from about 15 to 85 km.

9. PERIOD OR TIME: 1) December 24, 1985 02:50 LT
2) December 25, 1985 04:55 LT

10. STATION: Middle latitudes of USSR

11. RESOLUTION AND ACCURACY: Vertical resolution <0.5 km. Error about 50%. Three ranges of sizes.

12. DATA EXAMPLE: Vertical profiles of aerosol obtained in December 25, 1985 04:55 LT.



13. DATA FORMAT:

14. NOTES:

USSR MAP DATA CATALOGUE 3

1. SUBJECT: Rocket measurements of vertical electric field and conductivity

2. PRINCIPAL INVESTIGATOR(S): Dr. A.A.Tyutin

3. AFFILIATION: Division for Atmospheric Research, Novosibirsk State University

4. ADDRESS: Novosibirsk 630090, USSR

5. TELEPHONE: | 6. TELEX:

7. INSTRUMENT(S) OR SYSTEM: The rocket cylindrical "field-mill" system and relaxation sensor for electrical conductivity.

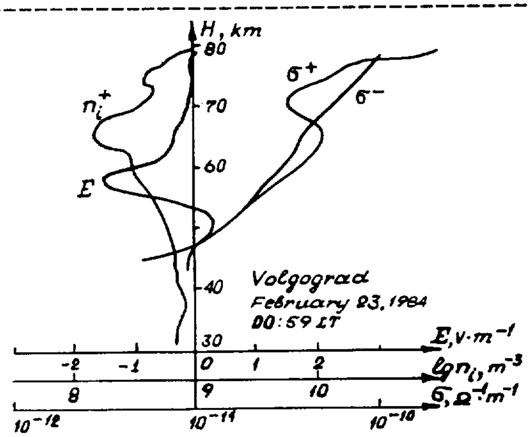
8. OBSERVED PARAMETER(S): Vertical electric field intensity, positive and negative conductivities.

9. PERIOD OR TIME: 1) December 10, 1983 02:20 LT; 2) December 10, 1983 03:00 LT; 3) December 20, 1983 03:00 LT; 4) December 21, 1983 03:05 LT; 5) January 19, 1984 01:05 LT; 6) January 19, 1984 03:10 LT; 7) February 23, 1984 00:59 LT.

10. STATION: (1,4,5) - Heiss Is. (81 N, 58 E)
(2,3,6,7) - Volgograd (49 N, 44 E)

11. RESOLUTION AND ACCURACY: Vertical resolution <0.2 km. Error about 50%.

12. DATA EXAMPLE: Vertical electric field intensity, conductivities and positive ions density obtained in February 23, 1984.

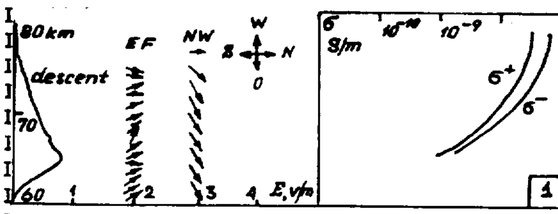


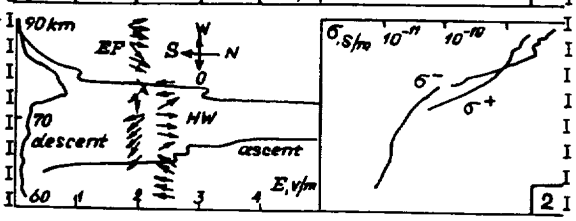
13. DATA FORMAT:

14. NOTES: In the 1st-3rd, 6th and 7th launches the positive ions density were measured.

USSR MAP DATA CATALOGUE 4

1. SUBJECT:	Rocket measurements of electric field and conductivity
2. PRINCIPAL INVESTIGATOR(S):	Dr. V.I.Struminsky
3. AFFILIATION:	Division for Atmospheric Research, Novosibirsk State University
4. ADDRESS:	Novosibirsk 630090, USSR
5. TELEPHONE:	6. TELEX:
7. INSTRUMENT(S) OR SYSTEM:	The rocket "mother-daughter" system, symmetric double probes (E-field), relaxation sensor.
8. OBSERVED PARAMETER(S):	Horizontal electric field intensity and direction, positive and negative conductivities at mesospheric altitudes.
9. PERIOD OR TIME:	1) November 10, 1983 05:30 LT 2) January 19, 1984 03:20 LT
10. STATION:	Volgograd (49 N, 44 E)
11. RESOLUTION AND ACCURACY:	Vertical resolution <0.2 km. Error about 30%.
12. DATA EXAMPLE:	Electric field intensity (E) and direction (EF), conductivities, horizontal wind direction (HW).
13. DATA FORMAT:	
14. NOTES:	Struminsky V.I. Mesospheric horizontal electric field as the results of rocket experiment. - Kosmicheskie Issledovaniya, 1986, Vol. 24, No. 6, p. 938-941.





USSR MAP DATA CATALOGUE 5

1. SUBJECT: Rocket measurements of ions number density

2. PRINCIPAL INVESTIGATOR(S): Dr. V.N.Kikhtenko
   Dr. Yu.A.Bragin

3. AFFILIATION: Division for Atmospheric Research, Novosibirsk State University

4. ADDRESS: Novosibirsk 630090, USSR

5. TELEPHONE: 6. TELEX:

7. INSTRUMENT(S) OR SYSTEM: The rocket-borne spherical wire-net condenser

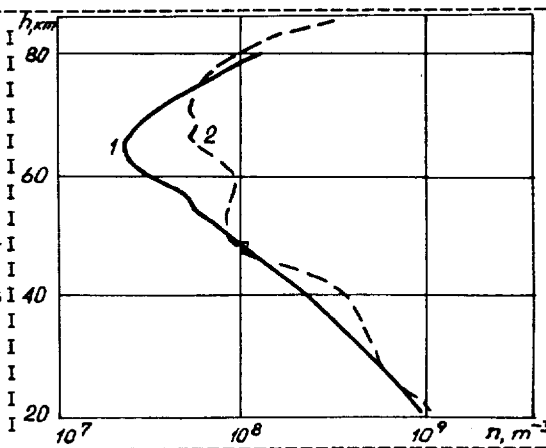
8. OBSERVED PARAMETER(S): The ions number density altitude distribution from about 30 to 90 km.

9. PERIOD OR TIME: October 1977; August 1978; December 1980; January 1981; March 1982; October 1982; winter 1983/1984; November 1984; July 1985.
   Total - 20 profiles.

10. STATION: Volgograd (49 N, 44 E)

11. RESOLUTION AND ACCURACY:
    Vertical resolution <0.5 km.
    Error about 50%.

12. DATA EXAMPLE:
    Vertical profiles of ions number density obtained in winter 1983/1984:
    1 - December 10, 1983;
    2 - February 23, 1984.



13. DATA FORMAT:

14. NOTES: Kikhtenko V.N. In-situ researches of electric properties of the atmosphere with the spherical wire-net condensers. - Kosmicheskie Issledovaniya, 1978, Vol. 16, No. 4, p. 626-629.

USSR MAP DATA CATALOGUE 6

1.SUBJECT: Rocket measurements of ions density

2.PRINCIPAL INVESTIGATOR(S): Dr. L.N.Smirnykh

3.AFFILIATION: Division for Atmospheric Research, Novosibirsk State University

4.ADDRESS: Novosibirsk 630090, USSR

5.TELEPHONE: | 6. TELEX:

7.INSTRUMENT(S) OR SYSTEM: The rocket-borne plane multigrid analyzer

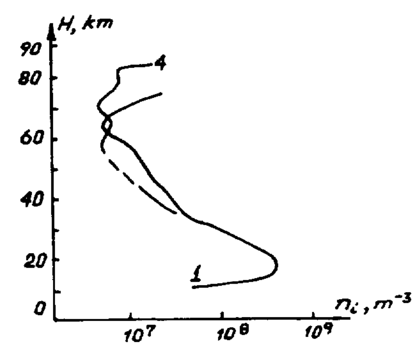
8.OBSERVED PARAMETER(S): Positive ions density in the middle atmosphere

9.PERIOD OR TIME:
1) December 10, 1983 02:20 LT; 2) December 10, 1983 03:00 LT;
3) December 20, 1983 03:00 LT; 4) January 19, 1984 03:10 LT;
5) February 23, 1984 00:59 LT.

10.STATION: (1) - Heiss Is. (81 N, 58 E)
(2-5) - Volgograd (49 N, 44 E)

11.RESOLUTION AND ACCURACY:
Vertical resolution <0.5 km.
Error about 30-50%.

12.DATA EXAMPLE:
Vertical profiles of ions density (1) and (4).



13.DATA FORMAT:

14.NOTES: In the same launches the vertical electric field and electric conductivity were measured.

1. SUBJECT: Meteor radar observation

2. PRINCIPAL INVESTIGATOR(S): Doctor K.Karimov and Laboratory of atmospheric Processes

3. AFFILIATION: Institute of Physics, Academy of Sciences of Kirghizia

4. ADDRESS: Lenin avenue, 265-a, Frunze, Kirghizia, USSR, 720071

5. TELEPHONE: 24-35-19

6.

7. INSTRUMENT(S) OR SYSTEM: Meteor Radar (Frequency: 36,5 MHz, transmitted power: 40-60 kW/pulse, wavelenth - 8,13 m, pulse duration 40-50 mks, pulse frequency 300 Hz, antenna is a five-element wave channel.

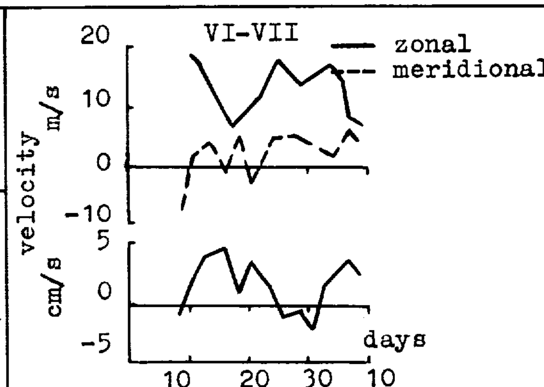
8. OBSERVED PARAMETER(S): Radial wind velosity, zonal, meridional and vertical wind components, prevailing wind, tides, internal gravity waves, characteristics of horizontal wind nonuniformity.

9. PERIOD OR TIME: From January 1979 till to present time. Data have been obtained during of MAP/MAC calendar observations and constantly once a week.

10. STATION: Institute of Physics, Academy of Sciences of Kirghizia, Frunze (42°N, 72°E).

11. RESOLUTION and ACCURACY: Error of radial velocity is 3-5 m/s. Resolution: Data were taken at a middle level 93 km.

12. DATA EXAMPLE: Day-to-day variations of zonal, meridional and vertical wind components in summer 1986. The values of vertical velocity are several cm/s.



13. DATA FORMAT: Tables

14. NOTES: The observations are continuing. The longest period of data covers more then one year.

1. SUBJECT: Lidar observations

2. PRINCIPAL INVESTIGATOR(S): V.E. Zuev, G.M. Krekov, V.N. Marichev

3. AFFILIATION: Institute of Atmospheric Optics

4. ADDRESS: Akademichesky Ave, 1, Tomsk, 634055, USSR

5. TELEPHONE: 1-84-52, 1-81-11(ext) 4-97   6. TELEX:

7. INSTRUMENT(s) OR SYSTEM: Lidar (Transmitted power (time mean) 1 W,3000 pps for the wave-length 532 nm. Diameter of receiving telescope 1 m. Quantum efficiency of the photomultiplier 5%)

8. OBSERVED PARAMETERS: Backscattering coefficient and scattering ratio in the stratosphere and upper troposphere for the wave-length 532 nm.

9. PERIOD OF TIME: Since January 1986. Up to ten days a month

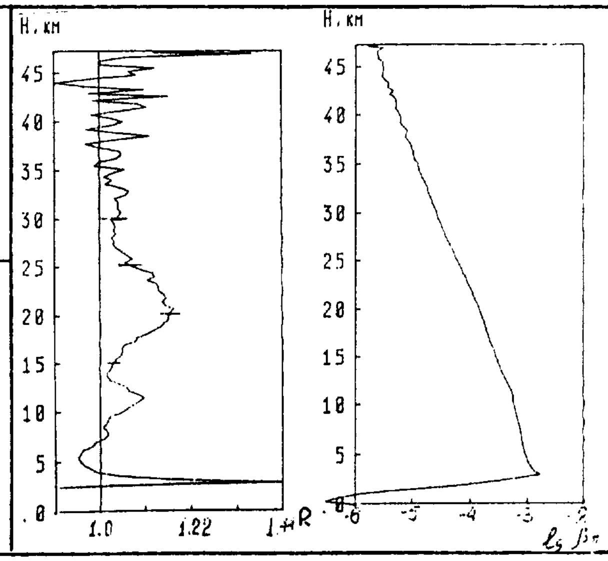
10. STATION: Tomsk, West Siberia

11. RESOLUTION AND ACCURACY:

Vertical resolution 0.3 km. Standard error about 10% at the altitude of 30 to 35 km

12. DATA EXAMPLE:

Vertical profiles of backscattering coefficient and scattering ratio of the aerosol



13. DATA FORMAT:

(Not specified)

14. NOTES: Molecular component of backscattering coefficient is computed from radiosonde data from nearby meteorological stations (at distances of 210 and 240 km from lidar site) with time delay of about 4-6 months. The profiles of backscattering coefficient and scattering ratio just after observations are obtained using models of molecular atmosphere

1. SUBJECT: Lidar observations

2. PRINCIPAL INVESTIGATORS: V.E.Zuev, G.M. Krekov, B.V. Kaul

3. AFFILIATION: Institute of Atmospheric Optics

4. ADDRESS: Akademichesky Ave, 1, Tomsk, 634055, USSR

5. TELEPHONE: 1-84-52 6. TELEX:

7. INSTRUMENT(S) OR SYSTEM: Lidar (Transmitted power 50 mJ/pulse, 25 pps for the wavelength 532 nm. Diameter of receiving telescope 0.5 m. Quantum efficiency of the photomultiplier 8%)

8. OBSERVED PARAMETERS: Backscattering coefficient and scattering ratio at altitudes of 5 to 35 km.

9. PERIOD OF TIME: March to October 1987

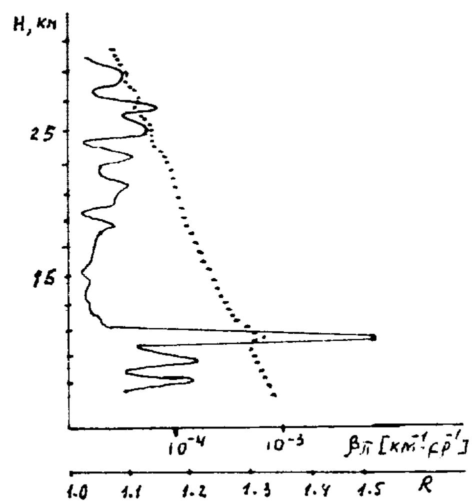
10. STATION: Tomsk, West Siberia

11. RESOLUTION AND ACCURACY:

Vertical resolution 0.5 km. Error about 10% at the altitude of 30 km

12. DATA EXAMPLE:

Vertical profiles



13. DATA FORMAT:

(Not specified)

14. NOTES: Molecular component of backscattering coefficient is computed from radiosonde data from nearby meteorological stations (at distances of 210 and 240 km from lidar site) with time delay of about 4-6 months. The profiles of backscattering coefficient and scattering ratio just after observations are obtained using models of molecular atmosphere.

1. SUBJECT: Lidar observations

2. PRINCIPAL INVESTIGATORS: B.T. Tashenov, V.A. Lyadzhin

3. AFFILIATION: Institute of Astrophysics, Academy of Sciences of Kazakhstan SSR

4. ADDRESS: Alma-Ata, 480068, USSR

5. TELEPHONE: 62-40-40 6. TELEX:

7. INSTRUMENTATION(S) OR SYSTEM: Lidar (Transmitted power 15 mJ/pulse, 50 pps for 532 nm. Diameter of receiving telescope 1 m. Quantum efficiency of the photomultiplier 8%).

8. OBSERVED PARAMETER(S): Scattering ratio at altitudes of 10 to 40 km

9. PERIOD OF TIME: Since January 1986. One time a month

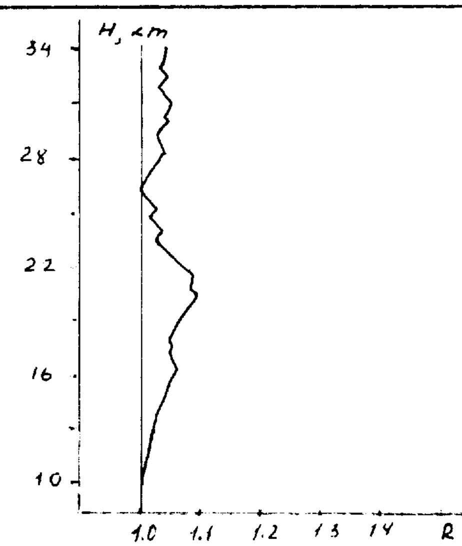
10. STATION: Alma-Ata, Kazakhstan, 2900 m above sea level

11. RESOLUTION AND ACCURACY:

Vertical resolution 1 km. Error about 10% at an altitude of 30 km

12. DATA EXAMPLE:

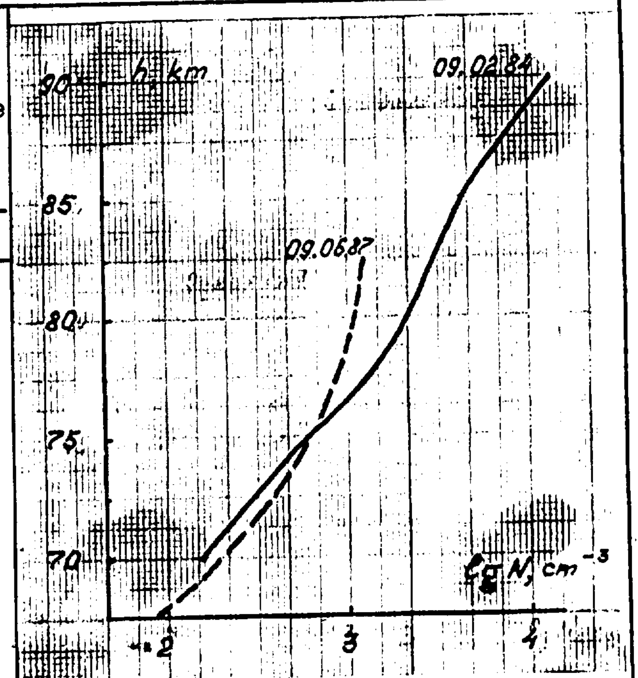
Vertical profiles of ratio of total scattering to molecular one



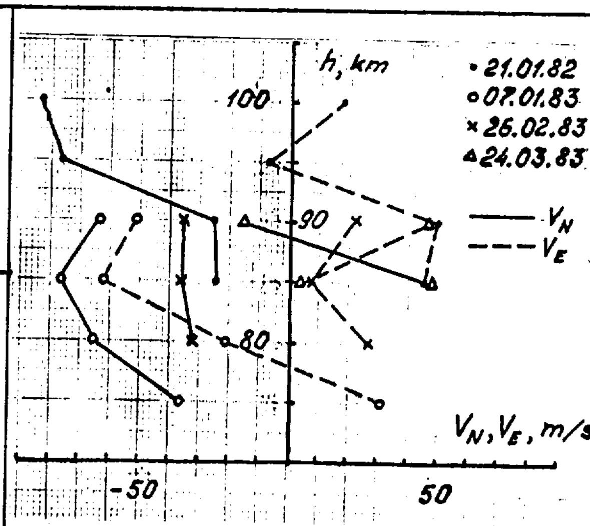
13. DATA FORMAT:

(not specified)

14. NOTES: Determination of the tropopause altitude and backscattering ratio calculations are performed using radiosonde data at lidar site

1. SUBJECT: Partial reflection techniques	
2. PRINCIPAL INVESTIGATOR(S): V.V.Belikovich, E.A.Benediktov, V.D.Vyakhirev, N.P.Goncharov	
3. AFFILIATION: Research Institute of Radiophysics	
4. ADDRESS: Lyadova Street, 25/14, Gorky, 603155, USSR	
5. TELEPHONE:	6. TELEX:
7. INSTRUMENT(S) OR SYSTEM: Partial reflection facility (Frequency 2.95 MHz, pulse length 50 mcs, pulse power 100 kW, transmitter antenna aperture 40,000 m^2, spacing of receiving antennae $\sim$100 m)	
8. OBSERVED PARAMETERS: Wind velocity and direction at altitudes of 75 to 100 km during daytime	
9. PERIOD OR TIME: January 1982, December 1982 to March 1983	
10. STATION: Gorky (56.15°N, 44.3°E)	
11. RESOLUTION AND ACCURACY: Resolution: Data were taken at levels with 5 km spacing. Accuracy: (Not specified)	
12. DATA EXAMPLE: Results of wind measurements for separate days	
13. DATA FORMAT: Results of measurements presented as tables	
14. NOTES: (i) During the 1-st period measurements were performed during local noon, during the 2-nd period--during first half of the day	

ORIGINAL PAGE IS OF POOR QUALITY

1. SUBJECT: Partial reflection techniques	
2. PRINCIPAL INVESTIGATOR(S): V.V.Belikovich, E.A.Benediktov, V.D.Vyakhirev, N.P.Goncharov	
3. AFFILIATION: Research Institute of Radiophysics	
4. ADDRESS: Lyadova Street, 25/14, Gorky, 603155, USSR	
5. TELEPHONE: TELEX:	
7. INSTRUMENT(S) OR SYSTEM: Partial reflection facility (Frequency 2.95 MHz, pulse length 25 to 50 mcs, pulse power 100 kW, antenna aperture 40,000 m^2)	
8. OBSERVED PARAMETERS: Electron numerical density profile at altitudes of 65 to 95 km by differential absorption techniques	
9. PERIOD OR TIME: (i) November 1983 to March 1984. (ii) June to July 1987.	
10. STATION: Gorky (56.15°N, 44.3°E)	
11. RESOLUTION AND ACCURACY: Resolution: Data were taken at levels with 2.5 km spacing. Accuracy: (Not specified)	
12. Profiles of electron numerical density	
13. DATA FORMAT: Results of measurements presented as tables	
14. NOTES: (i) During periods cited daily observations were performed. (ii) Profiles averaged over 30 minutes intervals weree submitted to World Data Center B2. (iii) The results of observations are published in Belikovich V.V. et al. J. Atmosph. Terr. Phys. 1986, 48, No 11-12, 1241-1245.	

SOVIET MAP DATA CATALOGUE

I. SUBJECT: Rocket measurements of D region electron density profiles at the polar, mid-latitude and equatorial stations.

2. PRINCIPAL INVESTIGATORS: Dr. S.V.Pakhomov and A.K. Knyazev.

3. AFFILIATION: Central Aerological Observatory (CAO).

4. ADDRESS: Dolgoprudny, Moscow Region, I4I700, USSR.

5. 6.

7. INSTRUMENT: Nose-tip DC-probe at M-IOOB rocket, calibrated by propagation technique.

8. OBSERVED PARAMETER: $n_e(h)$ profiles up to appr. 85 km.

9. STATIONS/ Heiss Isl. ($8I^oN$, 58^oE), Volgograd (49^oN, 44^oE) Thumba (08^oN, 77^oE), Molodejnaya (68^oS, 46^oE).

IO. PERIOD: Since I983 at Heiss Isl, since I979 at Volgograd and Thumba, since I984 at Molodejnaya. Generally weekly observations. Total number of profiles is about 75o.

II. RESOLUTION AND ACCURACY: Estimated accuracy is about 35 %.

I2. DATA EXAMPLE: Selected $n_e(h)$ profile with some associated information in computer printed form.

See annexure

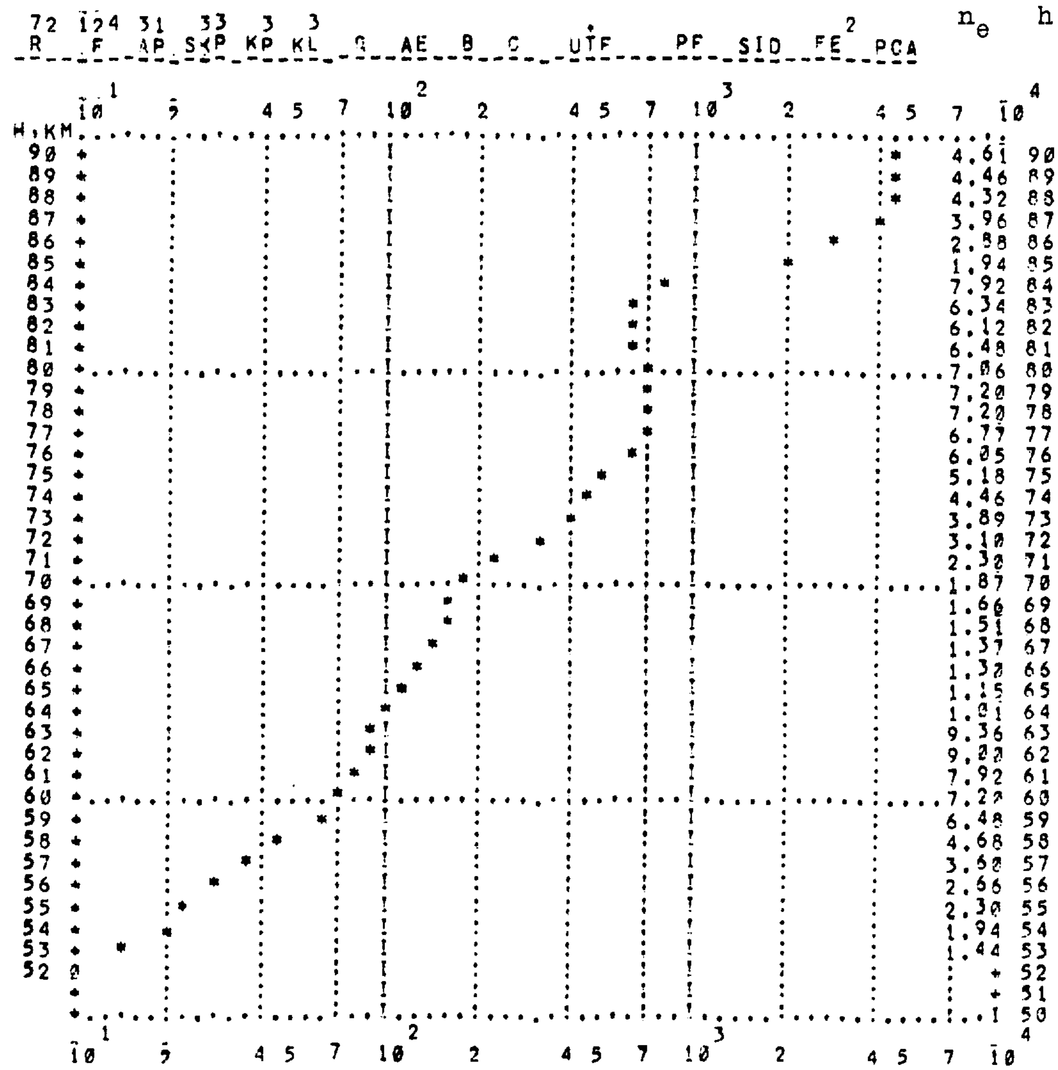
I3. DATA FORMAT: MT EC computer. Each $n_e(h)$ profile is accompanied by temperature and wind data up to appr. 80 km, measured in the same rocket flight. Solar and geomagnetic indices are included also.

I4. Notes: (i) The observations are continuing. (ii) Details of the calibration technique and procedure should be referred to/ V.M.Sinelnikov, G.P.Lvova, T.L.Gulyaeva, S.V.Pakhomov, A.P.Glotov "A rocket radiobeacon experiment on the electron density profile measurements in the bottomside of the ionosphere" Proc. Satellite Beacon Symp., Warszawa, Poland, I980 p.453.

S	MN	FN	LAT	LONG	DATE	UT	Z	SEN
8	039	1049	48.7	44.3	30.08.78	04.20	71	361

T75	TSP	T30	VZ95	VM95	VZ80	VM80	VZ60	VM60	VZ30	VM30
-81	-12	-45	-6	21			-7	-21	-2	-10

R	F	AP	SKP	KP	KL	G	AE	B	C	UTF	PF	SID	FE	PCA
72	124	31	33	3	3								2	



DATA EXAMPLE

MIDDLE ATMOSPHERE RESEARCH DURING THE MAP PERIOD

1.SUBJECT: Radar observations of meteor trail drift in Kharkov.

2.PRINCIPAL INVESTIGATORS: Prof. B.L.Kascheev, Cand.Sc. B.V. Kalchenko, Cand. Sc. V.V.Lizogub, Cand.Sc. V.A.Nechitailenko.

3.AFFILIATION: RADIO RESEARCH LABORATORY, INSTITUTE of Radioelectronic, Kharkov, U.S.S.R.

4. ADDRESS: 14, LENIN AVENUE, KHARKOV, 310726, USSR.

5. TELEPHONE: 43-17-58.

6. TELETYPE: 125416 KHARKOV "RECTOR".

7. INSTRUMENTS OR SYSTEM: The VETA-2 meteor radar (center frequency: 36,9 MHz; transmitted pulse power: 40 kW; pulse width: 40ms; sounding frequency: (500+100) s^{-1}; receiver sensitivity: 1 mkV; pass band: 50 kHz; transceiver antennas: four sets of dual 5-element Yagi pointed to the cardinal points).

8.OBSERVED PARAMETERS: Zonal and meridional components of horizontal wind velocity; the prevailing wind, diurnal, semidiurnal, "48-hour" components; long period (multi-diurnal) and seasonal variations of wind velocity.

9. PERIOD OR TIME: Since 1977 to 1987.

10. STATION: 50^{o} N; 36^{o} E.

11. RESOLUTION AND ACCURACY: Root-mean-square (rms) error of radial velocity measurement: 3 m s^{-1}; slant range; 0,5 km.

12. DATA EXAMPLE (shown in Figure): average diurnal estimate variations of the prevailing wind velocity, amplitudes and phases of the semi-diurnal tide for the zonal and meridional directions (Fig.1).

13. DATA FORMAT: Date, time, slant range, radial velocity, the variance of the radial velocity determination in one meteor, azimuth, the average hourly estimate of horizontal velocity in eath of 4 sounding directions, the variance of this estimate and recording statistic (stored on magnetic tape).

14. NOTES: Measurements were carrying monthly for 7-10 days; the duration of individual cycles reached to 60 days.

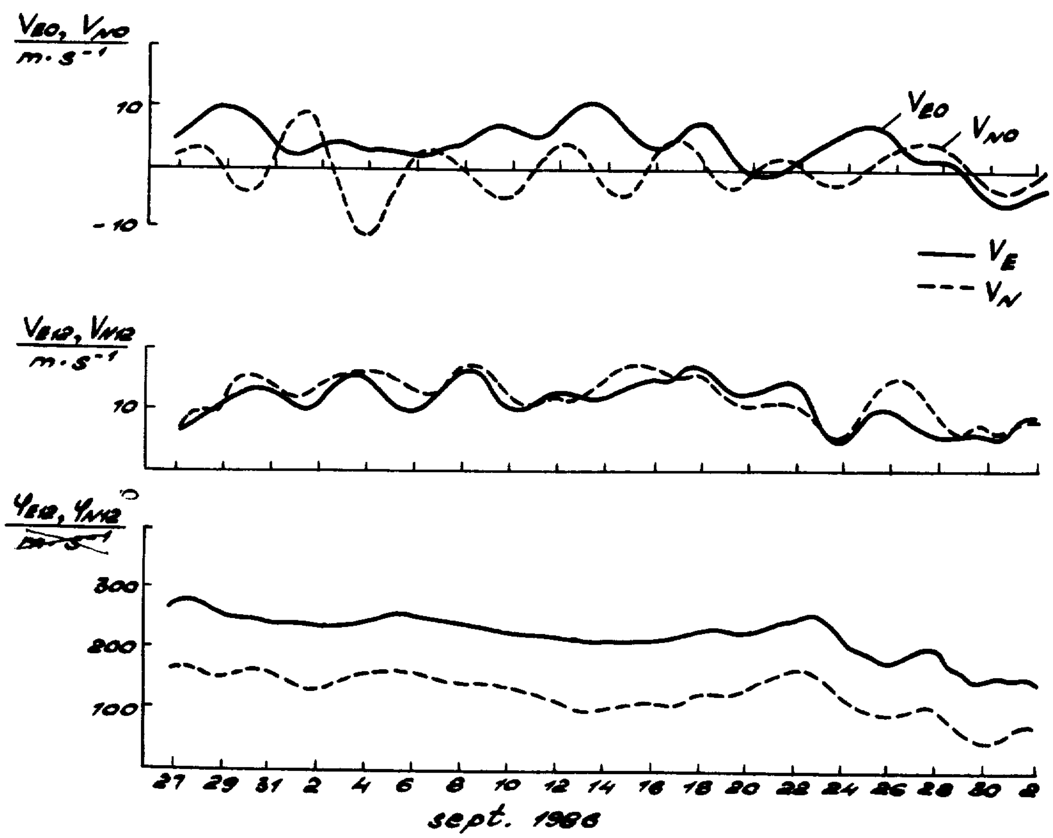


Fig.1

MIDDLE ATMOSPHERE RESEARCH DURING

THE MAP PERIOD

1. SUBJECT: Height wind velocity distribution in the meteor zone over Kharkov.
2. PRINCIPAL INVESTIGATORS: Prof. B.L.Kascheev, Cand.Sc. V.V.Zhukov, Cand.Sc. A.N.Oleinikov, Cand.Sc. V.N. Oleinikov.
3. AFFILIATION: Radio Research Laboratory, Institute of Radioelectronic, Kharkov, USSR.
4. ADDRESS: 14, LENIN AVENUE, KHARKOV, 310726, USSR.
5. TELEPHONE: 43-17-58.
6. TELETYPE: 125416 KHARKOV "RECTOR".
7. INSTRUMENTS OR SYSTEM: Automatic goniometer of the meteor automatised radar system AG MARS. The measurements technique of angular coordinates-phase; range measurements - pulse, time. Frequency: 3,1 MHz, pulse width: 30 mks, sounding frequency: (500+100) s^{-1}, transmitted pulse power: 300 kW, receiver sensitivity with s/n=2 is 0,8 mkV, pass band: 60 kHz, transmitting antenna: 5 element Yagi, receiving antennas: the system of five 5-element Yagi; bases are pointed to the cardinal points.
8. OBSERVED PARAMETERS:

   i) zonal wind velocity component by drift fixed in space of meteor trail; the prevailing wind, diurnal, semi-diurnal and "48-hour" components, long period (multy-diurnal) and seasonal variations of wind velocity; internal gravity waves (1-8 hrs),

   ii) the distribution of meteor echoes in time and space;

   iii) the amplitude-time characteristic of signals scattered by meteor trail is able to determine a number of meteor and atmosphere parameters.

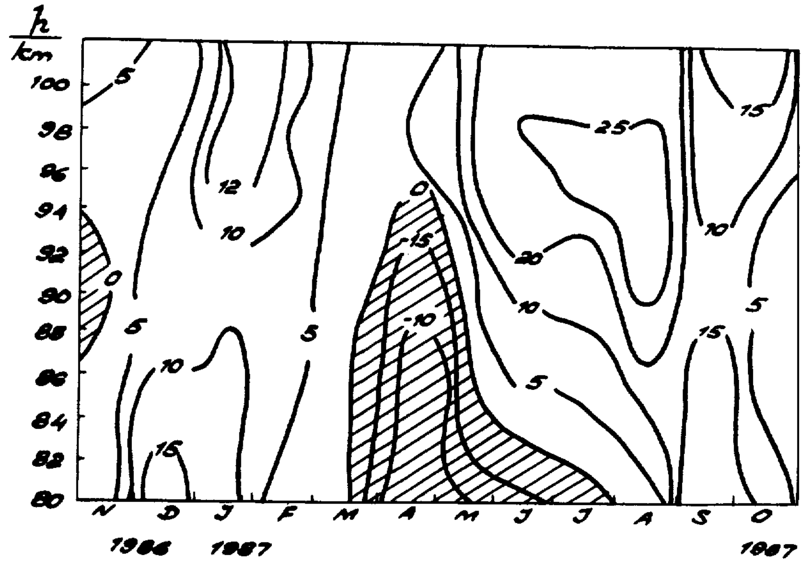
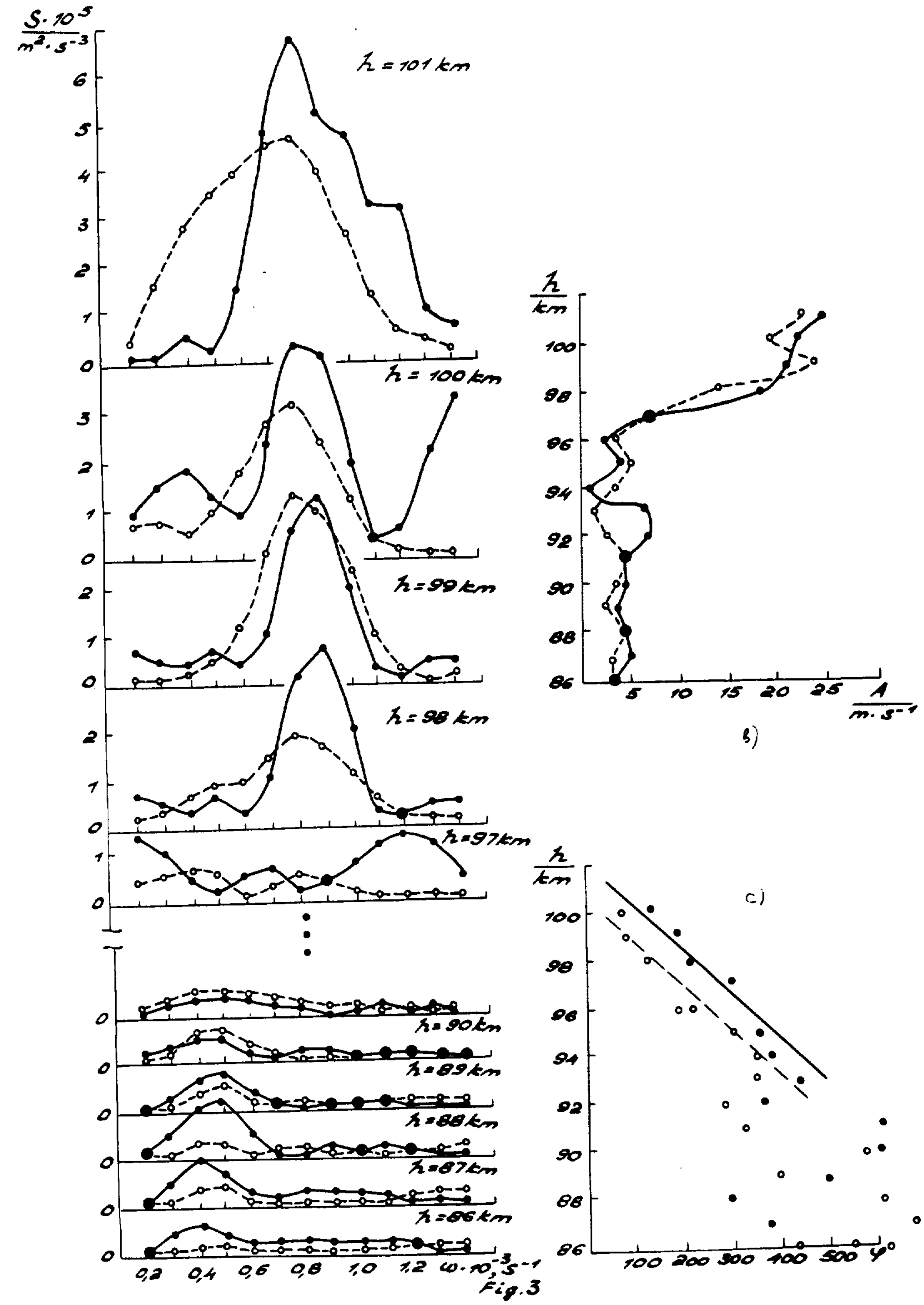

h/km
100
98
96
94
92
90
88
86
84
82
80
5
12
10
0
6
10
15
5
0
-15
-10
25
20
10
5
15
10
15
5
N
D
J
F
M
A
M
J
J
A
S
O
1986
1987
1987

Fig. 2



S·10^5 / m²·s⁻³
h = 101 km
h = 100 km
h = 99 km
h = 98 km
h = 97 km
h = 90 km
h = 89 km
h = 88 km
h = 87 km
h = 86 km
ω·10⁻³, s⁻¹
h / km
A / m·s⁻¹
b)
c)
φ°

Fig.3

9. **PERIOD OR TIME:** Since 1977 to present.

10. **STATION:** Kharkov (50° N, 36° E).

11. **RESOLUTION AND ACCURACY:** Root-mean-square error of the angular coordinate determination of 17 angular minutes, slant range - 200 m; height - 1 km, radial velocity - 3 m s^{-1}.

12. **DATA EXAMPLE** (shown in Fig. 2.3): Seasonal variations of height structure of the prevailing wind in the meteor zone, figure 2 (in the hatched area the direction of wind velocity is from east to west). Internal gravity wave breaking (height variations of wind velocity spectrum (Fig. 3a), amplitude and phase-height characteristics of waves (Fig. 3 b,c).

13. **DATA FORMAT:** Date, time, slant range, height, azimuth, elevation, radial velocity, the variance of the obtained estimate of radial velocity are stored on magnetic tape or perforated tape.

14. **NOTES:**

i) In individual time intervals measurements are simultaneously carried out by means of 2 AG. The 2-nd goniometer may be pointed in a sampled direction before hand. Output data of goniometers are practically the same.

ii) Measurements are usually carried out during 6-10 days, individual cycles covered up to 40 days.

MIDDLE ATMOSPHERE RESEARCH DURING THE MAP PERIOD

1. SUBJECT: Circulation of the atmosphere in the stratosphere and troposphere.
2. PRINCIPAL INVESTIGATORS; Prof. B.L.Kascheev, Cand.Sc. V.N.Oleinikov, A.B.Dudnic, O.A.Solyanic, S.L.Semenukha, A.B.Haly.
3. AFFILIATION: RADIO RESEARCH LABORATORY, INSTITUTE of Radioelectronic, Kharkov, USSR.
4. ADDRESS: 14, LENIN AVENUE, KHARKOV, 310726,USSR.
5. TELEPHONE: 43-17-58.
6. TELETYPE: 125416 KHARKOV "RECTOR".
7. INSTRUMENTS OR SYSTEM: The ST(Stratosphere-Troposphere) radar. Frequency: about 50 MHz, transmitted pulse power: 500 kW, average power: 8 kW, effective antenna aperture: 1600 m^2.
8. OBSERVED PARAMETERS:
   i) radial components of vertical, zonal and meridional components of wind velocity;
   ii) power spectra of echoes in 3 directions.
9. PERIOD OR TIME: Since 1985 to present. In individual cycles of measurements the duration covers 1-7 days.
10. STATION: Kharkov (50° N, 36° E).
11. RESOLUTION AND ACCURACY: The ST radar is able to give a height resolution of 450 m and time resolution of more 4 min. for one direction (in measurements in 32 altitude levels); the measurement error of wind velocity depends on the range of investigated velocities, in the range of $\pm$ 50m s^{-1} the error is about 1 m s^{-1}.

12. DATA EXAMPLE (shown in Fig.4). Power spectrum of an echo.

13. DATA FORMAT: 1/2 magnetic tape or 8 floppy disk, standard of operational system RT -11.

14. NOTES: More details of the ST radar should be referred to the book: "The Global Meteor observation System (GLOBMET)", Moscow, Academy of Sciences of the USSR, Soviet Geophysical Committee, 27-34, 1987.

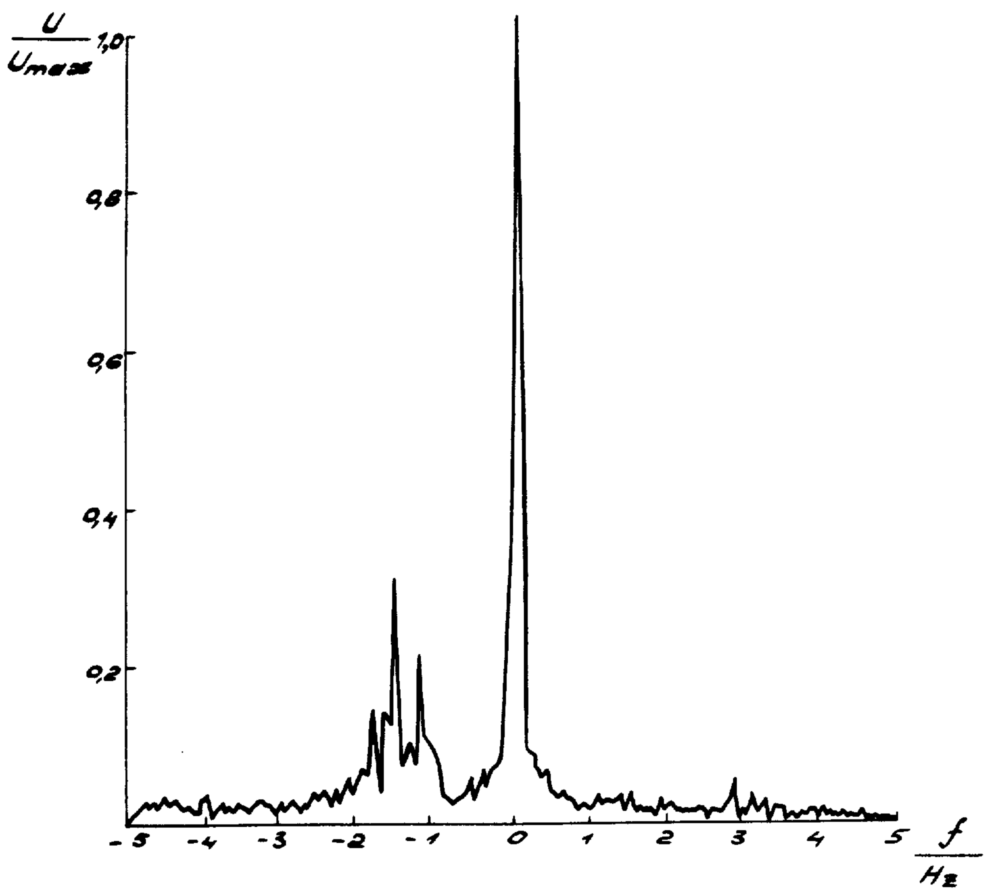


Fig.4

1. SUBJECTS: Riometric observations of cosmic radionoise absorption (CNA)
2. PRINCIPAL INVESTIGATOR(S): Dr.V.D.Sokolov, S.N.Samsonov
3. AFFILIATION: Institute of Cosmophysical Research and Aeronomy
4. ADDRESS: Lenin Ave., 31, Yakutsk, 677891, USSR
5. TELEPHONE: 2-25-51 6. TELEX: 135-131 Photon
7. INSTRUMENT(S) OR SYSTEM: Riometer 32 MHz. A net of 7 stations within latitudes with L= 3-8 at geographical longitude 130°E. Antenna is 5-element wave channel directed towards celestial pole
8. OBSERVED PARAMETER(S): Geometry and dynamics of CNA region. Small-scale processes of energetic electron precipitation
9. PERIOD OR TIME: The onset of observations at separate stations in 1984. The whole net operates since 1987.
10. STATION: Kotelny (76°N; 138°E), Sagylakh-Ary (73°N; 129°E), Tixie Bay (72°N; 129°E), Kyusyur (71°N; 128°E), Dzhardzhan (69°N; 124°E), Zhigansk (67°N; 123°E), Yakutsk (62°N; 130°E)
11. RESOLUTION AND ACCURACY: Analogue record at drawing speed 60 mm/h. The determination accuracy of absorption value 0,2 dB
12. DATA EXAMPLE:
13. FD (IBM Format)
14. NOTES: Continiouus observations

1. SUBJECTS: Optical Spectral Observations
2. PRINCIPAL INVESTIGATOR(S): Dr.V.M.Ignatyev, P.P.Ammosov
3. AFFILIATION: Institute of Cosmophysical Research and Aeronomy
4. ADDRESS: Lenin Ave., 31, Yakutsk, 677891
5. TELEPHONE: 2-25-51 6. TELEX: 135-131 Photon
7. INSTRUMENTS OR SYSTEM: 3-azimuthal spectrometer (viewing angle 6°, spectral resolution 1,4 nm. Time resolution 2-4 min. 3 channels at 45°Z form an equiangular triangle at 88 and 94 km height the OH and O_2(0,I) luminosity, respectively.
8. OBSERVED PARAMETERS: OH emissions intensity and rotational temperature and O_2(0,I) emission intensity. On their variations by Blackman-Tukey statistical spectral analysis are determined periods and horizontal phase speeds of a propagation of inner gravitational waves in mesosphere
9. PERIOD OR TIME: January-February, 1982; December, 1982; January-March, 1983; December, 1985; January-March, 1986; December, 1986; January-March, 1987; December, 1987; January-March, 1988
10. STATION: Maimaga (63°N; 129,5°E)
11. RESOLUTION AND ACCURACY: A normal error of emission intensity measurements ±10%, of statistical temperature ±20%
12. DATA EXAMPLE:

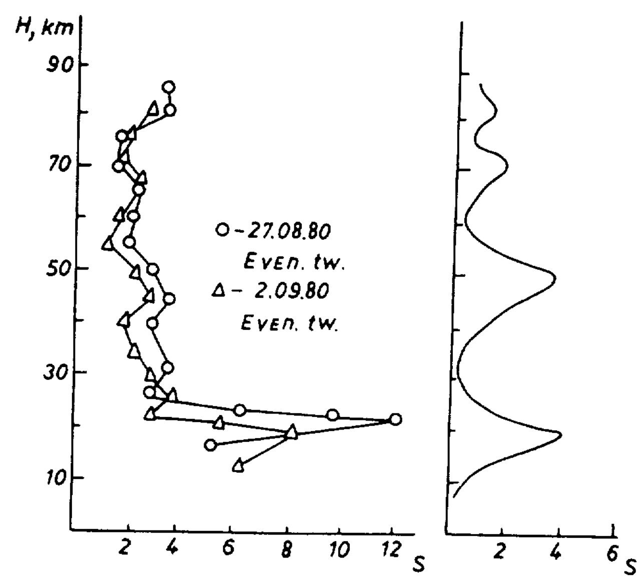
13. FD (IBM Format)

14. NOTES: (i) The observations are carried out in moonless, clear nights without aurora. (ii) A maximum duration reaches 15 hours. (iii) The description of instrument and the analysis methods should be referred to: Geomagnetizm i aeronomiya, 1986, t.26, No.6, p.936; "Vysokoshirotnaya ionosfera i magnetosferno-ionosfernye svyazi", Apatity, 1986, p.38.

1. SUBJECTS: Interferometric observations
2. PRINCIPAL INVESTIGATOR(S): Drs.V.M.Ignatyev, V.A.Yugov
3. AFFILIATION: Institute of Cosmophysical Research and Aeronomy
4. ADDRESS: Lenin Ave., 31, Yakutsk, 677891, USSR
5. TELEPHONE: 2-25-51 6. TELEX: 135-131 Photon
7. INSTRUMENT(S) OR SYSTEM: Photographic Fabry-Perot interferometer with electronic-optical transformer having a scanning system of mirrors with the help of which is carried out a successive photographing of interference images in 557,7 nm in the zenith and at zenith angles 60-70° in meridional and zonal directions. The viewing angle 2,5°, spectral resolution $6 \cdot 10^{-5}$ nm, exposure 8-10 min
8. OBSERVED PARAMETER(S): Temperature, speed and direction of neutral wind
9. PERIOD OR TIME: January-March, 1988;
10. STATION: Maimaga (63°N; 129,5°E)
11. RESOLUTION AND ACCURACY: Temperature measurement error ±60K; neutral wind speed ±30 $m \cdot s^{-1}$
12. DATA EXAMPLE: Data are obtained in films. The treatment is made by microphotometers and comparators
13. FD (IBM Format)

14. NOTES: (i) Observations are carried out in moonless, clear nights and during aurora. (ii) A maximum duration 13-14 hours. (iii) The descroption of instrument and treatment method should be referred to: Geofizicheskiye issledovaniya na shirotakh avroralnoi zony. Yakutsk, Yakutski Filial SO AN SSSR, 1986, s.102-120

1. SUBJECT: Twilight sounding
2: PRINCIPAL INVESTIGATORS: Prof. T. G. Megrelishvili, Dr. G. G. Mateshvili, Dr. Yu. D. Mateshvili
3. AFFILIATION: Abastumani Astrophysical Observatory, Georgian SSR A. S., Mount Kanobili
4. ADDRESS: Abastumani, 383762 USSR
5. Telephone: 2-11
6. TELEX: 327409 TERMIT
7. INSTRUMENTS OR SYSTEM:
   (i) Photoelectric photometer (wavelengths: 397 and 527 nm)
   (ii) Photoelectric photometer (wavelengths: 610 nm)
   (iii) Multichannelphoton-counting photometer (wavelengths: 423, 474, 496, 542, 610, 642, 678, 714, and 821 nm)
   (iv) Spectrograph (wavelengths: 550-700 nm)
8. OBSERVED PARAMETERS:
   Intensity and polarization of twilight scattered radiation
9. PERIOD OF TIME:
   The data were obtained in 1942 to 1952, 1968 to 1971, 1978 to 1987, 1962-1987
10. Abastumani Astrophysical Observatory, USSR (41°8N, 42°8 E)
11. RESOLUTION AND ACCURACY:
    Altitudinal error $\pm$ 1.5 to 2 km. Error in intensity measurements $\pm$ 1.5%.
12. DATA EXAMPLE:
    Mean vertical profile of turbidity and some turbidity profiles for particular days.
13. DATA FORMAT:
    MT: Soviet "ES"-type IBM-compatible computer.
14. -



INVESTIGATION OF THE MIDDLE EARTH'S ATMOSPHERE
FROM THE MAP PROGRAM
(materials for the catalogue being prepared by the
Soviet commission of MAP)

1. Subject of investigation: Regularities of time and space wind parameter variations in the meteor zone.

2. Main researchers: Yu.I.Portnyagin, I.A.Lysenko, B.I.Petrov, P.P.Mikhailik, N.A.Makarov, N.I.Vlasov, and S.V.Lebedev.

3. Organization: The Institute of Experimental Meteorology of the USSR State Committe for Hydrometeorology.

4. Address: USSR, 249020, Obninsk, Kaluga region, Lenin street, 82.

5. Position of observation sites and equipment parameters:

Observations are carried out at five sites with coherent-pulse meteor radars. The sites, their coordinates and main parameters of equipment are given in the table.

Observation site	Coordinates	Working frequency (mHz)	Power in pulses (kWt)	Repetition frequency (Hz)	Pulse duration (mks)	Receiver band (kHz)
Heiss Island	80,5°N,58°E	33,45	40	500	35	50
Obninsk	55°N,38°E	33,3	12	500	60	20
Khabarovsk	49°N,135°E	27,9	12	300	100	15
Volgograd	49°N,44°E	33,5	35	500	35	50
Molodezhnaya station (Antarctica)	67°S,46°E	33,7	35	500	35	50

The receiving-transmitting antennas are the five-element Yagi. In Volgograd, on Heiss Island and at Molodezhnaya station the zonal and meridional wind components are measured by orienting the antennas in the N and E directions every 30 minutes. In Obninsk and Khabarovsk these components are measured by electron switching of antennas (with the frequency 100 Hz) oriented in four directions (N,E,S,W).

6. Observed parameters: zonal and meridional wind velocity components at middle levels of the meteor zone ($\sim$95 km). From measured parameters we investigate: latitudinal, interdiurnal and seasonal variations of prevailing wind velocities, amplitudes and phases of diurnal and semidiurnal tides; coupling of the wind regime parameter variability with the thermal stratospheric regime.

7. Operation time:

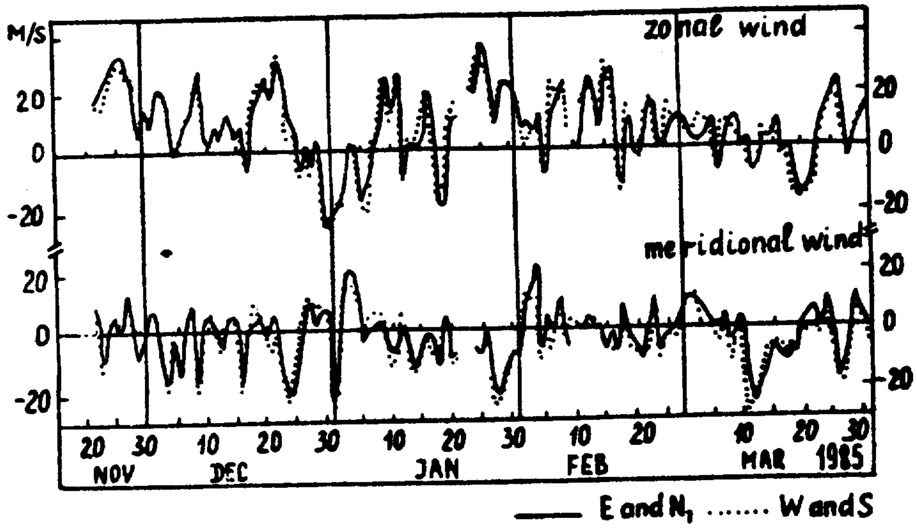
Observation site	Operation time
Heiss Island	from 1965 to date
Obninsk	from 1964 to date
Khabarovsk	from 1976 to date
Volgograd	from 1967 to date
Molodezhnaya station	from 1968 to date

8. Resolution and accuracy: root-mean-square errors of range measurement is $\pm$(3-5)km; hourly mean wind velocity values $\pm$(3-6)m/s.

9. Example of obtained data: interannual variations of zonal and meridional prevailing wind velocities from data for Obninsk in 1984-85 (see the figure).

10. Data format: the technical carries is the punched tape on which the information about time, slant range, radial velocity of meteor drifts, sounding direction are registered.

11. Note: measurements are carried out on Heiss Island and in Volgograd during a day every week (mainly on Wednesday and Thursday); in Khabarovsk during several days every week; in Obninsk practically continuously.


M/S
zonal wind
meridional wind
20
0
-20
20 30 10 20 30 10 20 30 10 20 10 20 30
NOV DEC JAN FEB MAR 1985
E and N, ... W and S

Researches of the Earth's Middle Atmosphere (MAP programme)

K.A. Karimov

1. Object of research: The research of dynamical processes in the middle atmosphere.
2. Main researchers: prof. K.A.Karimov, R.D.Gainutdinova, R.B.Bekbasarov, M.A.Takirbashev.
3. Organization: Institute of Physics Academy of Sciences of Kirgizia, Laboratory of Atmospheric Processes.
4. Adress: USSR, 720071, Frunze , Leninski prospect, 265A.
5. Apparatus: Wavelength-8,13m, pulse duration 40-50 mks, sensitivity of the receiver at s/n =2, is ~ 1mkV, pulse repetition frequency 300 Hz, power emission in the pulse - 60 kW, antenna is a five-element wave channel.
6. Parameters observed:

   a) zonal and meridional components of wind velocities by meteoric tracers drift, prevaling wind, tidal components, long-term (average monthly seazonal etc) wind velocities.

   b) Internal gravity waves, parameters of wave disturbances from solar terminator.

   c) Characteristics of horizontal wind nonuniformity comprising deformation of wind flux, horizontal divergence and vertical component of wind velocity.
7. Service durability; from 1971 till the present time.
8. Location of the observation station: Frunze (42°N, 72°E).
9. Resolution and accuracy: mean-square error of tilt distance is ±1km, of radial velocity is 3-5 $m \cdot sec^{-1}$.
10. Notes: Measurements were carried out during 10-15 days a month, including International geophysics days by all means. Some cycles lasted for 1 year and even more.

INVESTIGATION OF THE EARTH'S MIDDLE ATMOSPHERE ACCORDING TO MAP PROGRAM

1. The object of investigation: wind velocity in meteor zone above Dushanbe.
2. Principal investigators: Chebotarev R.P. Philin V.N., Nikonov A.M., Kotsyuruba D.J., Pushkareva T.A.
3. Organization: Tadjik Akademy of Sciences, The Institute of Astrophysics, radar laboratory.
4. Addres: The Institute of Astrophysics, st. Sviridenko 22, 734042 Dushanbe, USSR.
5. Equipment: an automatic meteor pulse radar MIR-3. The measurement method of wind velocity - according the velocity of doppler increase phases; range measurements - the pulse time method. Measurements are simultaneously in two directions (north and west).

   Operating frequency 37.4 MHz; pulse duration 40 μs; repetition frequency 500 pps; peak pulse power in each of two direction from 12 to 22 kW. Passband of receivers 50 KHz; the sensitility of receivers (recording level at signal/noise = =3) changes from 3 to 8 ÷ 10 μV in dependence on radio hindrances.

   Transmitting and receiving aerials are identical directed one pair to the west, and the ather to the north. During 1981-1984 single five-element Uda-Yagi at an angle of 45° towards the horizont; since 1985 doubled five-element Uda-Yagi at on angle of 40° towards the horizont.
6. The observed parametrs:

   a) The average hourly value of wind velocity in zonal and meridional directions and mean square errors these series of measurements. Prevailing wind, diurnal, semidiurnal and eight-hourly components.

b) The average hourly distribution of meteor reflections according to range and duration (in each direction).

7. A period of exploitation - since 1981 to the present (at present we have simultaneous measurements in 4 directions).

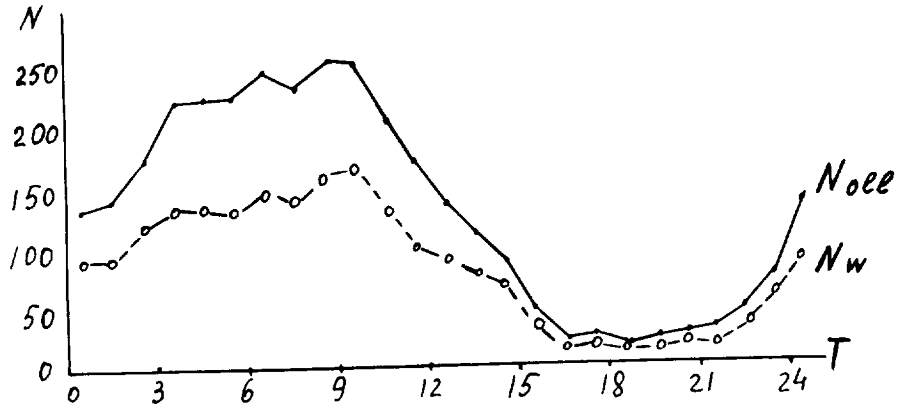
8. Place of observation: Dushanbe 38.5 N , 68.5E.

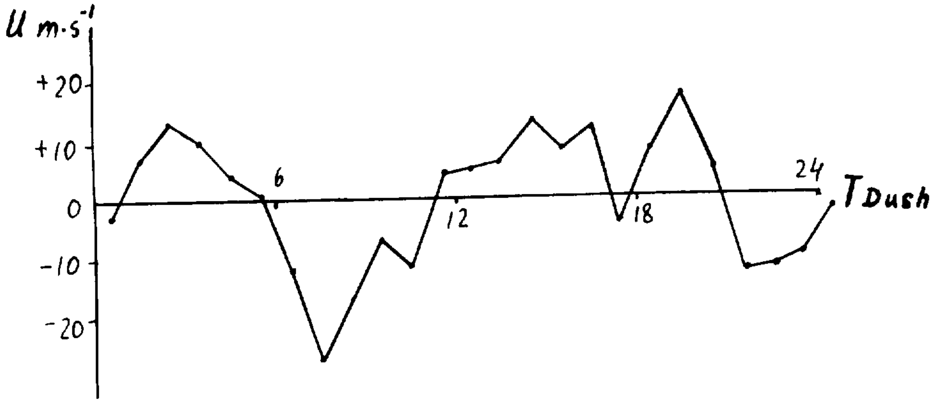
9. Resolving power and accuracy: mean square error in range determination is about 1 km, in radial velocity is about 2 ms^{-1}.

10. The example of data obtained is given in Fig. A diurnal variation in meteor rates (oll and with wind measurements) and wind velocity. North direction.

11. Date format: is hourly listing on paper tape in every direction of range and duration distributions (in 14 groups), the average wind velocity, mean square error in wind velocity and total namber of recorded meteors.

12. Notes: measurements are carried out every weck from 3÷4 O'clock (UT) on Wednesday till 4 O'clock on Thursday; in the period of activity of the Quadrantid, Lirid, Eta Aquarid, Perseid, Orionid, Geminid meteor showers the measurements lost 5 ÷ 12 days, and sometimes up to 30 day according to the wind programs.


N
250
200
150
100
50
0
0
3
6
9
12
15
18
21
24
T
Noll
Nw


U m·s-1
+20
+10
0
-10
-20
6
12
18
24
TDush

DATA CATALOG

1. SUBJECT: Vertical ionosonde sounding observation
2. PRINCIPAL INVESTIGATOR: Dr. M. I. Tevdorashvili
3. AFFILIATION: Ionospheric Observatory Tbilisi University
4. ADDRESS: Tbilisi, Chavchavadze av. 3, USSR
5. TELEPHONE: 99-90-21
6. TELEX:
7. INSTRUMENT OR SYSTEM: Vertical ionosonde sounding (AIS-5 and SP-3; frequency 1-20 MHz; Transmitted power: 6 kW; Antenna aperture: 60 deg)
8. OBSERVED PARAMETERS: Ionograms (H'f profile)
9. PERIOD OR TIME:
   Ionospheric data since 1963. Observations are regular in each 15 min and in RWD each 5 min.
10. STATION: Tbilisi Ionospheric Observatory (41.7°N, 44.8°E; Dip latitude 60)
11. RESOLUTION AND ACCURACY: 0.1 MHz, 5 km.
12. DATA EXAMPLE: Ionograms (on 35 mm film); Daily F plots; Daily/ hourly values and monthly summary data (medians, counts and quartiles) recorded on paper.
13. DATA FORMAT:
14. NOTES: Regular observations are continuing. For the special problems in 1980-1984 years were assumed ionograms by three space diversity ionosondes (distance between them 50 km). The observations are seasonal, ionograms -- after each 5 min on 35 mm film. For period and time of each observation apply to the principal investigator.

EARTH MIDDLE ATMOSPHERE RESEARCH ACCODING TO MAP PROGRAMME

1. Research object wind high-altitude speed distribution in meteor zone above Kazan.

2. Main researchers: professor Sidorov V.V., cand.of ph.m.sc. Fachrutdinova A.N. and Group in PRAL.

3. Institution: Radioastronomic problem laboratory of Kazan state university (PRAL).

4. Address: USSR, 420008, Kazan, Lenina st., 18.

5. Telephone 320920.

6. Telex Neptun.

7. Equipment: KGU-M5 automated radio-location complex with phase goniometer. Frequency - 32 MHz, impulse duration - 100 mcs, sound frequency - 400 Hz, transmitter impulse capacity - 200 kwt; transmitting antenna - double five-element "wave canal" type, receiving antenna - five three-element "wave canal" aerials,

8. Parametres observation:

a) wind velocity zonal and meridianal constituents of drifting recorded in meteor trace space; dominating wind; amplitudes and phases of diurnal, semidiurnal, 8-hour influxes of zonal and meridional circulation, waves with scales (1-8h), meteorological, season, interannual regularities of zonal and meridional circulation.

b) meteor radioecho amplitude distribution accoding to ten fixed levels.

c) meteor trace dispersed signals amplitude-time characteristics for determenation of number of meteor particles adn atmosphere parametres.

9. Exploitation time: from 1978 up to now.

10. Observation point location: town of Kazan (56°C, 49°B).

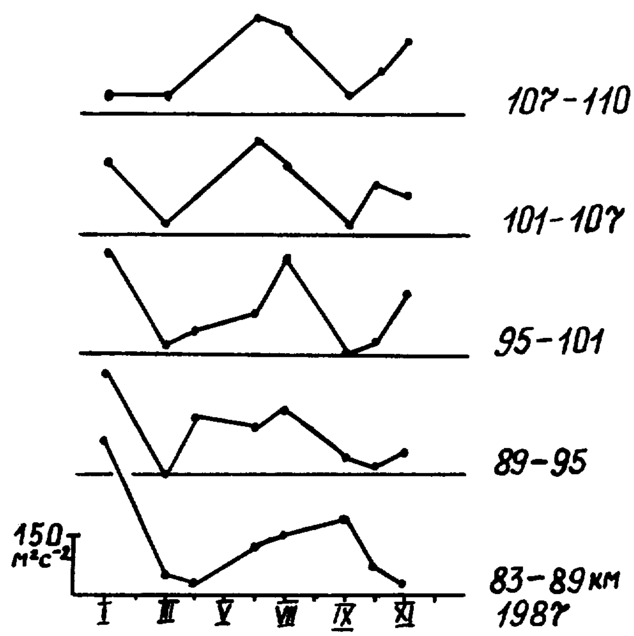
11. Resolution and accuracy: angular coordinate determination average quadratic error is 20 angular minutes, of stanting distance - 250 m, of altitude - 1 km, of radial velocity - 3 m/s^{-1}.

12. Data examples: The figure gives the altitude profiles seasonal dependency of dominating circulation energy (on unit of a mass) in the lower thermosphere according to observation in 1987.

13. Data format: The following is put to the magnetic tape: observation direction, the date, time, slanting distance, radiosignal phases from five aerials of phase interferometre or the values of the altitude, azimuth, reflecting point zenith angle on the

meteor trace, radial velocity and dispersion of the oblained valuation of radial velocity, of meteor particle speed valuation, ambipolar diffusion coefficients or amplitude meaning of meteor radiosignal amplitude-time characteristics; meteor radioecho amplitude distribution according to ten recorded levels.

14. Notes: The observations are continious during several days. The detailed explanation of the meteor radar can be got from scientific worker Makarov V.O., sc.w. Stepanov A.M., sc.w. Yanin V.A. The questions, concerning the observations methods and results, can be answered by senior as.w.Fahrutdinova A.N.



☆ U.S.GOVERNMENT PRINTING OFFICE:1991-282-851/40264

CUMULATIVE LISTING FOR THE MAP HANDBOOK

Volume	Contents	Publication Date
1	National Plans, PMP-1 , PMP-2, PMP-3 Reports, Approved MAP Projects	June 1981
2	Symposium on Middle Atmosphere Dynamics and Transport	June 1981
3	PMP-5, MSG-1, MSG-2, MSG-3 Reports, Antarctic Middle Atmosphere Project (AMA), EXOS-C Scientific Observations, WMO Report No. 5., Updated Chapter 2 of MAP Planning Document, Condensed Minutes of MAPSC Meetings	November 1981
4	Proceedings of MAP Assembly, Edinburgh, August 1981 Condensed Minutes of MAPSC Meetings, Edinburgh, Proceedings of MAP Open Meeting, Hamburg, August 1981,	April 1982
5	A Catalogue of Dynamic Parameters Describing the Variability of the Middle Stratosphere during the Northern Winters	May 1982
6	MAP Directory	November 1982
7	Acronyms, Condensed Minutes of MAPSC Meetings, Ottawa, May 1982, MAP Projects, National Reports, Committee, PMP, MSG, Workshop Reports, Announcements, Corrigendum	December 1982
8	MAP Project Reports: DYNAMICS, GLOBUS, and SSIM, MSG-7 Report, National Reports: Czechoslovakia, USA	July 1983
9	URSI/SCOSTEP Workshop on Technical Aspects of MST Radar, Urbana, May 1983	December 1983
10	International Symposium on Ground-Based Studies of the Middle Atmosphere, Schwerin, May 1983	May 1984
11	Condensed Minutes of MAPSC Meetings, Hamburg, 1983, Research Recommendations for Increased US Participation in the Middle Atmosphere Program, GRATMAP and MSG-7 Reports	June 1984
12	Coordinated Study of the Behavior of the Middle Atmosphere in Winter (PMP-1) Workshops	July 1984
13	Ground-Based Techniques	November 1984
14	URSI/SCOSTEP Workshop on Technical Aspects of MST Radar, Urbana, May 1984	December 1984
15	Balloon Techniques	June 1985
16	Atmospheric Structure and its Variation in the Region 20 to 120 km: Draft of a New Reference Middle Atmosphere	July 1985
17	Condensed Minutes of MAPSC Meeting, Condensed Minutes of MAP Assembly, MAP Project, MSG, and National Reports	August 1985
18	MAP Symposium, Kyoto, November 1984	December 1985
19	Rocket Techniques	March 1986
20	URSI/SCOSTEP Workshop on Technical and Scientific Aspects of MST Radar, Aguadilla, October 1985	June 1986
21	MAPSC Minutes, ATMAP Workshop, Atmospheric Tides Workshop, MAP/WINE Experimenters Meetings, National Reports: Coordinated Study of the Behavior of the Middle Atmosphere in Winter	July 1986
22	Middle Atmosphere Composition Revealed by Satellite Observations	July 1986
23	Condensed Minutes of MAPSC Meetings, Toulouse, June/July 1986	September 1986
24	MAP Directory	December 1986
25	First GLOBMET Symposium, Dushanbe, August 1985	May 1987
26	MAPSC Minutes, Abstracts and Report of Workshop on Noctilucent Clouds, Boulder,	August 1987
27	COSPAR Symposium 6, The Middle Atmosphere After MAP,Espoo, July 1988, MAPSC Minutes, Espoo, July 1988; Workshop on Noctilucent Clouds, Tallinn, July 1988	June 1988 October 1985 April 1989
28	URSI/SCOSTEP Workshop on Technical and Scientific Aspects of MST Radar, Kyoto, November/December 1988	August 1989
29	International Symposium on Solar Activity Forcing of the Middle Atmosphere, Liblice, Czechoslovakia, April 1989; MASH Workshop, Williamsburg, April 1986	September 1989
30	International School on Atmospheric Radar, Kyoto, November 1988	October 1989
31	Reference Models of Trace Species for the COSPAR International Reference Atmosphere (Draft)	December 1989
32	MAP Summary; MAPSC Minutes, Reading, August 1989; MAP Summaries from Nations; MAP Data Catalogue	January 1991